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Environmental Assessment

Waste Treatment Facility

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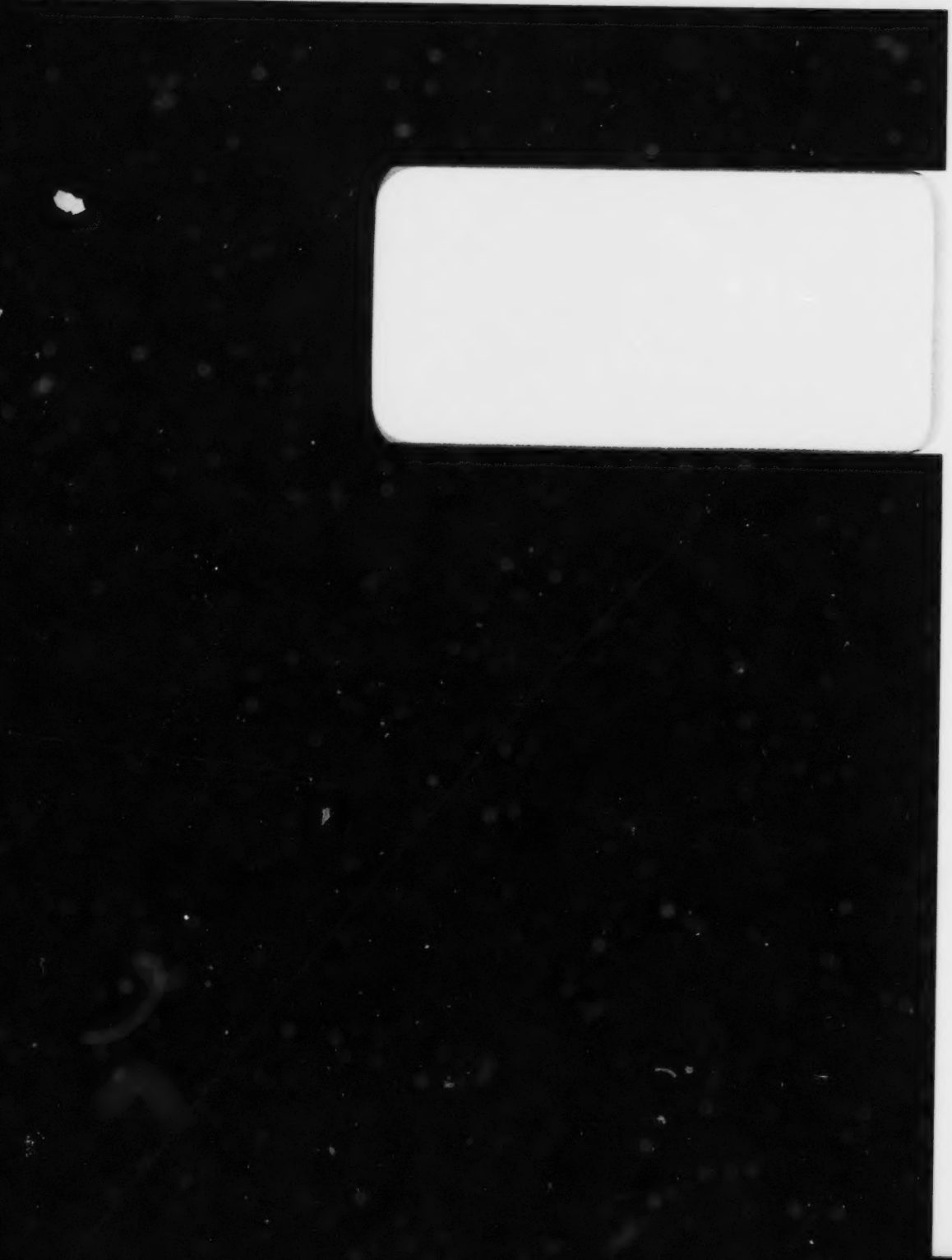

OWMC TREATMENT FACILITY
PROCESS AREA REPORT
ENGINEERED LANDFILL

Prepared
by

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For

Monenco Limited

November 1986

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17 November 1986
Letter No. 877
File No. 1.3.2/4.17.4

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Attention: Mr. R. V. Griffiths, P.Eng.
Project Manager

Gentlemen:

OWMC Treatment Facility
Monenco Contract No.: MNC 8084-2

Process Area Report
Engineered Landfill

We are pleased to submit herewith the draft report entitled: Process Area Report - Engineered Landfill. The report describes the rationale for the selection of technologies including the conceptual design of the engineered landfill of OWMC's proposed Facility for the treatment and disposal of liquid industrial and hazardous waste in Ontario.

We trust that this report meets the Corporation's requirements.

Yours very truly,

J. V. Fitzgerald, P.Eng.
Project Manager

ITC/jj

DILLON
Consulting Engineers & Planners

OUR FILE: 1022-50-9
YOUR FILE:

17 November 1986

Monenco Limited
P.O. Box 1540
St. Catharines, Ontario
L2R 7J9

Attention: Mr. I. Caines

OWMC Treatment Facility
Process Area Report
Engineered Landfill

Dear Sirs:

We are pleased to submit herewith the draft report entitled: Process Area Report - Engineered Landfill. The report describes the rationale for the selection of technologies including the conceptual design of the engineered landfill of OWMC's proposed Facility for the treatment and disposal of liquid industrial and hazardous waste in Ontario.

Yours truly,

M. M. DILLON LIMITED

P.C. Murray, P.Eng.
Project Manager

PCM:mrb
Attach.

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ENGINEERED LANDFILL

PROCESS AREA REPORT

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EXECUTIVE SUMMARY

PURPOSE OF THE REPORT

This report describes the rationale for the selection of a landfill concept and landfill features included in the conceptual design of the engineered landfill of OWMC's proposed Facility for the treatment of liquid industrial wastes and hazardous wastes. This report was prepared by M.M. Dillon Limited for Monenco Limited who are responsible for the preliminary engineering of the overall OWMC Treatment Facility.

Moreso than for other process areas that make up OWMC's Facility, the site setting must be considered in designing the engineered landfill. Site investigations are ongoing with completion scheduled for December 1986. As a result, portions of the conceptual design of the engineered landfill cannot be completed until after that time.

The background and rationale for including landfill disposal of treated residues in the design of OWMC's Facility has been presented in earlier reports (Ref: OWMC[12], OWMC[13], The Proctor & Redfern Group[16]). The choice of rotary kiln incineration, physical/chemical treatment, solidification and an engineered landfill as the four major components of the Facility was subsequently confirmed by A. D. Little of Canada Limited in their report entitled "Rationale for the Selection of Technologies for the Treatment and Disposal of Special Wastes in Ontario" - (Ref: A.D. Little[1]).

This report focuses on the alternative landfill concepts and devices which can be included as major features of an engineered landfill. The purpose of the landfill is for the disposal of solidified residues from waste treatment (hereafter referred to as solidified material and solidified mass once in place) and subsequent control of contaminants, released from the solidified mass, to the environment. The report describes the alternative concepts and technologies considered, the methodology used to compare and evaluate them and the results of the selection process. The report also describes how the proposed landfill concept and features have been combined into an engineered landfill system and outlines how the complete system has been or will be optimized to maximize the performance, flexibility, reliability and safety of the landfill operation.

The engineered landfill is made up of the following features:

- landfill concept (e.g. above-ground, conventional and shallow entombed);
- engineered devices (e.g. covers, liners and leachate collection systems);
- mode of operation (e.g. active and passive); and
- development method (e.g. cell, trench and area).

This Process Area Report (PAR) on the engineered landfill is one of five such reports which together cover all areas of OWMC's proposed Treatment Facility. The other PAR's are for Incineration, Physical/Chemical Treatment, Solidification and General Facilities (Ref: Monenco Limited[7,8,9,10]). These reports provide additional technical back-up data and information in support of the system design and operating description presented in the Facility Description report (Ref: Monenco Limited[6]). The hydrogeologic environment and performance evaluation portions of the landfill concept and features evaluation will be contained in a report titled Hydrogeologic Aspects of Landfill Design, Development, and Operation (Ref: GLAL[4]).

It is important to appreciate from the outset the contribution which the engineered landfill will make, as part of a treatment philosophy, in ensuring that OWMC's Facility can treat Ontario's special wastes in a manner which will minimize risk to human health and minimize environmental impact. This is explained below by identifying the waste treatment processes that will produce residues requiring disposal in the engineered landfill:

- Organic wastes delivered to OWMC's Facility, for treatment and disposal, in various physical forms, will be destroyed by high temperature thermal oxidation using a rotary kiln incineration system.

- The incineration system includes provisions for cooling the gaseous products of combustion (flue gases) and for treating the cooled flue gases to remove contaminants, prior to the cleaned gases being discharged to atmosphere via a stack.

- The physical/chemical treatment plant is designed to treat aqueous organic wastes which contain low concentrations of organic contaminants. Organic contaminants which

are recovered from these aqueous wastes will be incinerated. Aqueous wastes containing low concentrations of organics not amenable to treatment by physical/chemical processes will be incinerated directly.

- Inorganic wastes delivered to OWMC's Facility will be treated in the physical/chemical treatment plant. Residues from these treatment processes will be solidified and subsequently disposed of in the engineered landfill.

- Inorganic fly ash residues from the incineration plant will be disposed of in the engineered landfill after they have been solidified to produce a material which is both physically and chemically stable.

The engineered landfill provides a repository for the solidified material and for control of the release of residual contaminants within the solidified mass, to the surrounding environment, in a manner which minimizes risk to human health and minimizes environmental impact. This control is imposed by the landfill concept, the hydrogeologic setting and a system of engineered devices.

SCOPE AND METHOD

A systematic approach was used to evaluate and select the preferred combination of engineered landfill concept and features best suited for OWMC's Facility. The selected landfill features were optimized to ensure that OWMC's goals of minimizing risk to human health, environmental impact, and cost are achieved.

The following points summarize the methodology used to evaluate alternatives for the landfill concept, engineered devices and development method of the engineered landfill.

- Establish the major treatment objectives and key treatment philosophies for the proposed engineered landfill.
- Establish criteria and sub-criteria.
- Establish a list of potentially suitable alternatives for each landfill feature.
- Evaluate alternative landfill concepts based on the chosen criteria and select the preferred concept for inclusion in the conceptual design.
- Evaluate alternative systems of devices based on the chosen criteria and select the preferred system for inclusion in the conceptual design.
- Cross-check sensitivity of preferred concept and system of devices to mode of operation.
- Evaluate alternative development methods for the preferred landfill concept and system of devices based on chosen criteria and select preferred development method.
- Design and optimize the resulting engineered landfill to meet the objectives and philosophies established by OWMC.

PREMISES AND POSTULATES

OWMC has developed the following basic planning principles and guidelines which are central to technology selection and process design in all areas of the proposed Facility including the engineered landfill.

- Wastes must undergo treatment to the fullest extent possible using best available proven technology, prior to the safe disposal of the remaining treated residues.

- It is the Corporation's goals to:

  - minimize risk to human health;
  - minimize environmental impact; and
  - minimize the cost to OWMC and the people of Ontario.

The following additional premises provided by OWMC have been used as starting points for concept and feature selection and design of the engineered landfill.

- Whereas the other process areas of the Facility are designed for a particular rate of waste throughput, the landfill must be designed both to accept solidified material at a given production rate and to have the capacity to accept the total quantity of solidified material produced over the active operating life of the landfill.

- The incoming wastes will build steadily to 150 000 t/a by year 5. In the event that incoming wastes continue to build, the Facility will be capable of being expanded to 300 000 t/a with a corresponding increase in solidified material to be landfilled. For the purposes of selecting the landfill concept the 300 000 t/a scenario will be used.

- The three landfill concepts to be considered in this evaluation process will be above-ground, conventional and shallow entombed (Ref: GLAL[3]).

- The treated waste residues will be solidified to form a physically and chemically stable mass following curing in place in the engineered landfill.

- All of the Facility processes; incineration, physical/chemical treatment, solidification and engineered landfill will be located on the site.

In addition to these premises, there are a number of others which were identified for the purposes of conceptual design. They are presented in Section 4.2 under the following headings:

- Volume of Solidified Material
- Geotechnical/Hydrogeologic Criteria
- Facility Layout
- Leachate Quantities

Postulates are assumptions or hypotheses made by Dillon or other OWMC consultants which are basic to the approach used to evaluate alternatives and arrive at an optimum design. The key assumptions, treatment objectives and treatment philosophies which have influenced landfill concept and features evaluation and design are summarized as follows:

- Contaminants released from the solidified mass could produce a leachate quality of concern over a period of time measured in hundreds of years (Ref: GLAL[4]).

- The hydrogeologic environment of the site is as identified in Section 2.5 Physical Site Setting and the Geologic, Hydrogeologic and Geotechnical Setting report (Ref: GLAL[5]).

- Engineered devices, that provide for control of contaminant migration from the engineered landfill, will perform their design purposes for a period of time measured in tens of years (Ref: Appendix A).

- Since the life expectancy of devices is much shorter than the time frame expected for release of contaminants, the evaluation of alternatives should include an evaluation of the ability of the natural hydrogeologic setting to control contaminant migration (Ref: GLAL[4]).

- The solidification process used will depend on the solids content of the treated waste residues. High solids material after solidification will have soil-like properties that will allow for transportation by trucking or by conveyor to the engineered landfill and placement using earth moving equipment. Low solids material will be in a slurry form and will be pumped, by pipeline to the landfill and placed in bermed areas formed using the previously placed high solids material. This material will set in place.

- The quantities of treated residue will vary according to the solids content and quantity of the incoming wastes. The solidified waste quantities resulting from the treated residues will depend on the operating scenario for solidification. The range of solidified material production was defined by two operating scenarios called the "High Solidified Waste Case" and the "High Effluent Case".[1]

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1. The "High Solidified Waste Case" and "High Effluent Case" represent conservative extremes. In the "High Solidified Waste Case", liquid effluent from the physical/chemical treatment plant is solidified and sent to the landfill. This scenario was previously called Total Solidification. In the "High Effluent Case", excess treated effluent is discharged and residues are solidified prior to disposal in the engineered landfill. This scenario was previously called Partial Solidification (Ref: Monenco Limited[6]).

In addition, an intermediate operating scenario called the "Typical Operations Case" was developed to represent the expected normal production of solidified material.[1] As engineering design progressed in Phase 4B, the "Typical Operations Case" was used to evaluate engineered devices, development method and mode of operation. Finally, the "Typical Operations", "High Solidified Waste" and "High Effluent" solidified waste quantities were used in conceptual design (Chapter 4).

In addition to these postulates, there are a number of others which were identified for the purposes of conceptual design. These are presented in Section 4.2 under the following headings:

- Volumes of Solidified Material
- Geotechnical/Hydrogeologic Criteria
- Facility Layout
- Leachate Quantities

STATUS OF DATA

The quantities of solidified material for landfilling developed by Monenco (Ref: Monenco Limited[6]) were used for selection and optimization of the preferred landfill system. The range of volumes used in the evaluation reflects modifications and refinements made by Monenco as the evaluation program progressed. The four streams of material requiring disposal in the engineered landfill will vary depending on the types of wastes received at OWMC's Facility.

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1. The "Typical Operations Case" was based on waste quantities and characteristics information from similar waste treatment and disposal facilities (Ref: Monenco Limited[6]).

Much of the data used in the evaluation of alternatives is based on information from current literature, operating facilities, and from technology vendors.

The evaluation and optimization of the engineered landfill was supported by technical inputs from Monenco Limited and Gartner Lee Associates Limited (GLAL).

Modifications to the conceptual design may be required;

- where ongoing environmental impact assessment studies indicate that mitigation may be required, and/or

- where pre-submission consultation identifies concerns that should be mitigated

and these will be documented in the final report.

The following points summarize the primary features proposed for OWMC's engineered landfill following evaluation of alternatives.

- Shallow entombed landfill concept.
- A system of devices consisting of a native clay base, simple clay cover and underdrain.
- Area method of landfill development.
- Passive mode of operation for the underdrain.

These features are discussed below.

An assessment of the sensitivity of the selected features to the assumptions involved in the analysis was carried out. A summary of the assessment is outlined below for each of the selected features.

- Shallow Entombed Landfill Concept:

  - Shallow entombed landfilling provides long-term performance without reliance on engineered devices. This is important since engineered devices are assumed to fail in tens of years while production of leachate with a quality of concern could continue for hundreds of years.

  - Leachate release to the surface water and weathered zone pathways is minimized with the shallow entombed concept because the solidified material is placed below the weathered zone.

  - The shallow entombed concept provides flexibility for active or passive modes of operation and various systems of devices which improve short-term performance, particularly with regard to the ground water pathway.

- System of Devices Including Native Clay Base, Simple Clay Cover and Underdrain:

  - This system provides high short-term performance and flexibility for active or passive modes of operation.

  - The underdrain system will not be operated (i.e. no leachate collection). As such, it will have no effect on the performance of the system of devices. Therefore, the functioning of the simple clay cover and native clay base will dictate the performance of the engineered landfill.

  - The provision for the active mode of operation allows a high level of control should the leachate quality be of concern.

- Area Method of Landfill Development:

  - The only differences in the development methods considered were related to the economic and commercial criterion.

  - The issue of contaminant loading by the various development methods is being addressed by the impact assessment consultants. A final decision on the acceptability of the area development method will be made when this work is completed.

  - The area method of development has a relatively low cost based on a unit volume of material for disposal and it provides substantially longer landfill life than the other methods considered.

- Mode of Operation:

  - The mode of operation for the underdrain will be passive. This means the underdrain will not be operated to collect and remove leachate.

This report also describes a number of other aspects of the engineered landfill to a conceptual level. Optimization of the landfill system design will be completed when the site investigations are finished. The following provides a list of areas which require optimization and will be included in the final report.

- The preferred leachate collection system.

- Surface water management of both potentially contaminated and uncontaminated flows.

- Development and operating practices.

CHAPTER 1
INTRODUCTION

1.1 PURPOSE OF THE REPORT

This report describes the rationale for the selection of a landfill concept and landfill features included in the conceptual design of the engineered landfill for OWMC's proposed Facility for treating liquid industrial wastes and hazardous wastes.

Moreso than for other process areas that make up OWMC's Facility, the site setting must be considered in designing the engineered landfill. Site investigations are ongoing with completion scheduled for December 1986. As a result, portions of the conceptual design of the engineered landfill cannot be completed until after that time.

The background and rationale for including landfill disposal of treated residues in the design of OWMC's Facility has been presented in earlier reports (Ref: OWMC[12], OWMC[13] The Proctor & Redfern Group[16]). The choice of rotary kiln incineration, physical/chemical treatment, solidification and an

engineered landfill as the four major components of the Facility was subsequently confirmed by A. D. Little of Canada Limited in their report entitled "Rationale for the Selection of Technologies for the Treatment and Disposal of Special Wastes in Ontario" - (Ref: A.D. Little[1]).

This report focuses on the alternative technologies which can be included as major features of an engineered landfill. The purpose of the landfill is for the disposal of solidified residues from waste treatment (hereafter referred to as solidified material and solidified mass once in place) and subsequent control of contaminants, released from the solidified mass, to the environment. The report describes the alternative concepts and technologies considered, the methodology used to compare and evaluate them and the results of the selection process. The report also describes how the selected landfill concept and features have been combined into an engineered landfill system and outlines how the complete system has been or will be optimized to maximize the performance, flexibility, reliability and safety of the landfill operation.

The engineered landfill is made up of the following features:

- the landfill concept (e.g. above-ground, conventional and shallow entombed);
- engineered devices (e.g. covers, liners and leachate collection systems);
- mode of operation (e.g. active and passive); and
- development method (e.g. cell, trench and area)

Each of these features is defined in the glossary of terms located on Page 139.

This Process Area Report (PAR) on the engineered landfill is one of five such reports which together cover all areas of OWMC's proposed Treatment Facility. The other PAR's are for Incineration, Physical/Chemical Treatment, Solidification and General Facilities (Ref: Monenco Limited[7,8,9,10]). These reports provide additional technical back-up data and information in support of the system design and operating description presented in the Facility Description report (Ref: Monenco Limited[6]). Figure 1 shows how the PAR documents are associated with each OWMC Facility component. The hydrogeologic environment and performance evaluation portions of the landfill concept and features evaluation will be contained in a report titled Hydrogeologic Aspects of Landfill Design, Development, and Operation (Ref: GLAL[4]).

Chapter 2 of the report summarizes the policies and objectives of OWMC, defines landfill and the major landfill components, identifies the types and quantities of solidified materials[1] that are expected to be disposed of in the engineered landfill, identifies the physical setting of the Facility site and the basic assumptions (premises and postulates) which have governed the landfill concept and features evaluation and system design of the engineered landfill.

Chapter 3 then presents the results and conclusions of the technology evaluation process including reasons for either accepting or rejecting each alternative considered with respect to criteria and sub-criteria.

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1. Refers to high and low solids materials from the solidification process. Incinerator slag is also included in the materials to be landfilled.

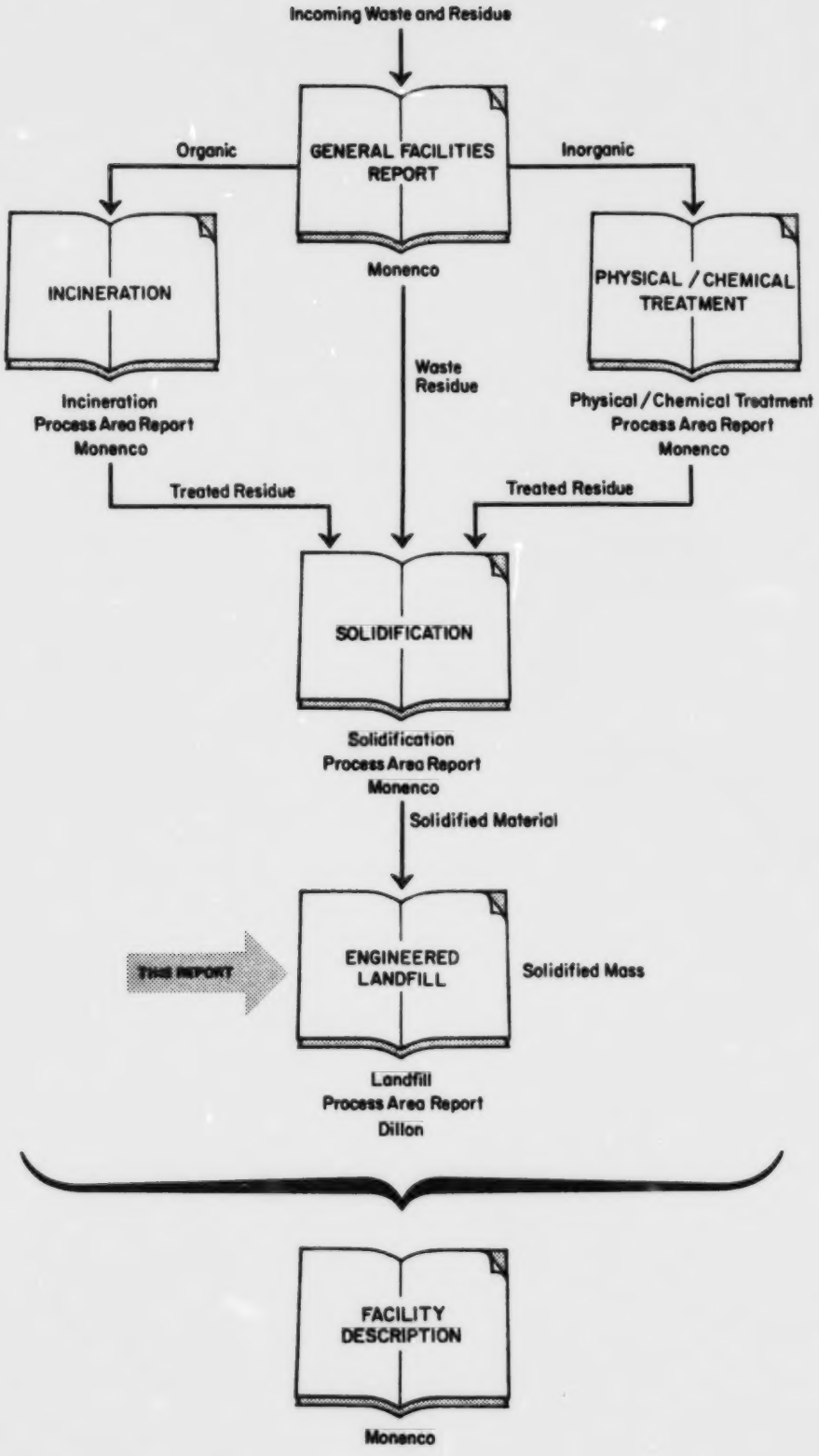


Figure I

FLOW DIAGRAM OF OWMC FACILITY COMPONENTS AND ASSOCIATED REPORTS

DILLON
Consulting Engineers · Planners
Environmental Scientists

Chapter 4 of the report describes the manner in which the proposed engineered design has been incorporated into the landfill concept. This chapter also outlines the manner in which the conceptual design of the total system has been or will be optimized.

This report was prepared for OWMC and Monenco Limited by M.M. Dillon Limited. Monenco Limited is responsible for preliminary engineering of the overall Treatment Facility. Dillon are subconsultants to Monenco responsible for the engineered landfill portion of the Facility.

The rationale for and undertaking of landfill concept and feature evaluation described in Chapter 3 of this report are provided by a Landfill Working Group. This group consisted of representatives from Monenco Limited, Gartner Lee Associates Limited (GLAL) and M.M. Dillon Limited.

Gartner Lee Associates Limited (GLAL) provided hydrogeologic input to the conceptual design of the engineered landfill. This input is documented in the GLAL report titled Hydrogeologic Aspects of Landfill Design, Development, and Operation (Ref: GLAL[4]). In summary, the GLAL report addresses the following:

- Hydrogeologic analysis used in comparison of the three alternate landfill concepts, namely conventional, above-ground and shallow entombed.

- Hydrogeologic analysis used in comparison of the three alternate development methods, namely cell, trench and area.

- Evaluation of the hydrogeologic performance of various designs for engineered devices (i.e. covers, liners, leachate collection systems).

- Input to the rationale for the development of systems of engineered devices.

- Hydrogeologic analysis used in comparison of alternative systems of engineered devices.

- Hydrogeologic analysis used in comparison of alternative modes of operation, namely active and passive.

The results of the hydrogeologic analyses noted above have been integrated into the comparative evaluations detailed in Chapter 3 of this report. The reader is referred to the GLAL report for a more detailed discussion.

1.2 PURPOSE OF THE ENGINEERED LANDFILL

It is important for the reader to understand the contribution which the engineered landfill will make as part of an overall treatment philosophy, in ensuring OWMC's Facility can treat Ontario's special wastes in a way that minimizes risks to human health, environmental impact and cost.

Wastes will be received at OWMC's Facility and classified by their chemical composition as either organic or inorganic in nature. The organic waste stream will be destroyed by incineration. The inorganic stream will be treated by the physical/chemical processes. The primarily inorganic residues from these processes, together with selected residues from waste generators, will be treated by solidification processes to produce a material which is both physically and chemically stable. These residues, treated by the above-mentioned processes along with incinerator slag material will be disposed of in the engineered landfill.

The engineered landfill provides a repository for the solidified residues from waste treatment (hereafter referred to as solidified material and solidified mass once in place) and for control of the release of residual contaminants within the solidified mass, to the surrounding environment, in a manner which minimizes risk to human health and minimizes environmental impact. This control is imposed by the landfill concept, the hydrogeologic setting and a system of engineered devices.

CHAPTER 2
BASIS FOR LANDFILL CONCEPT AND FEATURES SELECTION AND DESIGN

2.1 INTRODUCTION

An important aspect of the evaluation and selection of appropriate landfill concept and features for OWMC's Treatment Facility is to define the framework within which the proposed concept and features will operate. This framework is defined by:

- OWMC's philosophy;
- the type and quantities of solidified material which are to be placed in the landfill;
- the particular treatment objectives, philosophies and assumptions (premises and postulates) which have been applied to the design of the engineered landfill; and
- the role of the landfill in relation to those of the other major process areas (i.e. incineration, physical/chemical treatment and solidification) within OWMC's Facility.

2.2 OWMC PHILOSOPHY

OWMC has developed basic planning principles and guidelines which are central to technology selection and process design in all areas of the proposed treatment Facility including the engineered landfill. The following points summarize these key treatment philosophies.

- OWMC's primary responsibility is to establish and operate a liquid industrial waste and hazardous waste management system in Ontario. It has no responsibility for managing municipal solid waste or radioactive waste, nor is it a regulator of other industrial waste management systems (Ref: OWMC[12]).

- OWMC Facilities, no matter how large or small they ultimately may be, must be designed to handle all types of special waste. This full service capability is inherent in OWMC's responsibility as a provincial crown agency.

- Wastes must undergo treatment to the fullest extent possible, using the best available proven technologies, prior to the safe disposal of the remaining treated residues.

- The Corporation's goals, in order of priority, are:

  - minimize risk to human health;
  - minimize environmental impact; and
  - minimize the cost to OWMC and the people of Ontario.

2.3 LANDFILLING

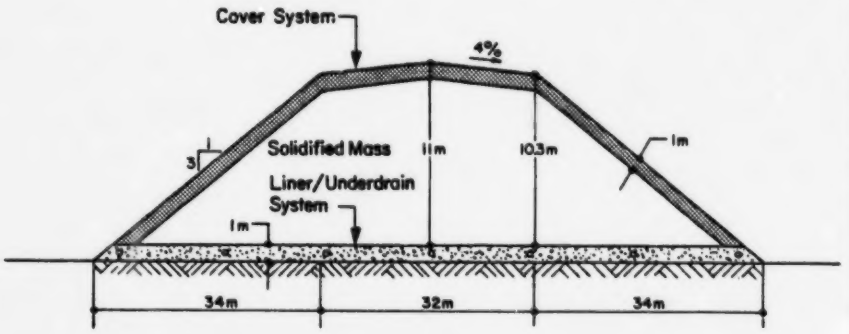
Landfilling can generally be described as a process for the disposal of wastes or other materials, on or in the surficial soils, by burial beneath a layer of soil which acts as a cover.

A number of landfill types or concepts have been used to dispose of wastes. The concepts vary as a result of the amount and characteristics of the material buried below or above the surface of the ground. On the basis of previous studies, three general types of landfill have been selected for detailed study: above-ground, conventional, and shallow entombed (Ref: GLAL[3]). In a conventional landfill, the materials are placed in excavations and the filling continues to form a mound above ground level. In an above-ground landfill, all materials are placed in a mound above ground level. In a shallow entombed landfill, materials are placed in excavations below the weathered zone of the native soils. For the OWMC site, materials will be placed below 5 m from ground surface. Schematic sections of these landfill concepts are shown in Figure 2.

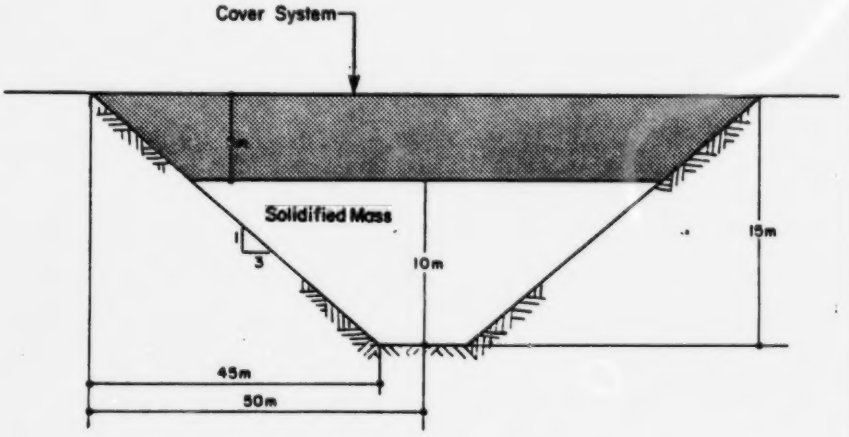
An engineered landfill departs from the general description of landfilling in that engineering principles are applied to control contaminant migration. The control features are referred to as devices. These devices can generally be categorized as covers, liners and leachate collection systems. Devices may be operated actively (requiring ongoing energy inputs such as for pumping) or left in the passive mode.

Several methods of development are possible. These refer to the configuration of the area in which the landfill materials are deposited (e.g. cell, trench and area).

Above - Ground Landfill



Shallow Entombed Landfill



Conventional Landfill

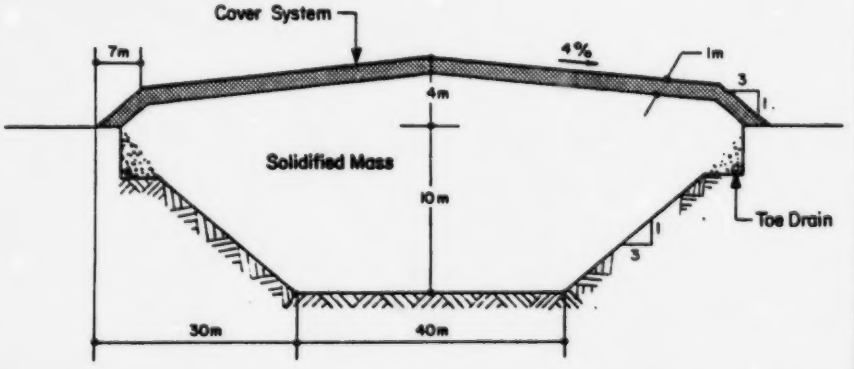


Figure 2

LANDFILL CONCEPTS IN SITE ADAPTED FORM

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Two major information bases are required in order to undertake the design of an engineered landfill. These are:

- Characteristics of the material to be disposed of;
- Characteristics of the natural environment in which the landfill will be located.

Knowledge of the material to be disposed of provides an indication of the stability of the landform created and the nature of contaminants to be controlled. The landfill relies, at least in part, on the natural hydrogeologic setting for control of contaminant migration. Knowledge of the natural setting permits assessment of this component of control.

2.4 MATERIALS TO BE LANDFILLED

Previous reports have identified the waste profile and quantities to be handled at OWMC's Facility (Ref: Monenco Limited[6]). Those materials will be treated by the incineration (organic wastes) or physical/chemical (inorganic wastes) processes (Ref: Monenco Limited[7,9]).

All treated waste residues will undergo solidification prior to being landfilled with the exception of incinerator slag. A summary of the materials that will be solidified is contained in the Monenco Process Area Report for Solidification (Ref: Monenco Limited[8]).

The high and low solids materials from solidification and incinerator slag will be landfilled. The quantity of solidified material is estimated to be approximately 100 000 t/a based on 150 000 t/a incoming waste (Ref: Monenco Limited[6]).

The high solids material will be transported to the landfill and will have a soil-like consistency.

The low solids material will have a slurry-like consistency and will be pumped by pipeline to the landfill. Deposit areas in the landfill will be formed by berming within the placed high solids solidified material. The low solids material will be placed in these areas for curing.

2.5 PHYSICAL SETTING OF THE SITE

The site is located in the central portion of the Niagara Peninsula, (see Figure 3).

The following description of the physical setting of the site was provided by Gartner Lee Associates Limited in the Phase 4A comparative evaluation of siting options:

> Site LF-9C is located on the Haldimand Clay Plain in West Lincoln Township. It is situated slightly north of the Salina-Guelph geologic contact and is underlain by dolostones of the Guelph Formation. Overburden varies from 30 to 35 m in thickness and consists of a lower silty till and clayey glacio-lacustrine deposits separated by clayey Halton Till. There is evidence from water well records for a discontinuous basal granular deposit, however, no such deposit was encountered in the GLAL boreholes. The two major hydrostratigraphic units are (1) a bedrock and granular aquifer and (2) a confining layer which usually extends from surface to the bedrock. The confining layer includes three sub-units which are (i) the lower till; (ii) the lower glacio-lacustrine unit, the

Figure 3
PREFERRED SITE
TOWNSHIP OF WEST LINCOLN, REGIONAL MUNICIPALITY OF NIAGARA. LOCAL DETAIL

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Source: OWMC, 1985

Halton Till and the unfractured portion of the upper glacio-lacustrine unit; and (iii) the surficial fractured portion of the upper glacio-lacustrine unit. The confining layer is between 30 and 35 m in thickness and is considered to be uniform and predictable. Ground water movement in the surficial fractured zone is primarily lateral and is characterized by potential flow rates of approximately 10 m per year. The surficial fracture zone has an expected depth of 5 m below grade. Flow in the unfractured clayey portions of the confining layer is essentially vertical and occurs at rates of approximately 0.007 m per year. Flow in the lower till is also considered to be mainly vertical and occurs at a rate of about 0.01 m per year. Ground water movement in the bedrock is considered to be primarily lateral in a southerly direction and to occur primarily in the upper fractured zone at flow rates of about 1600 m per year (Ref: GLAL[2], 1985).

There are three potential pathways for contaminant movement in the natural environment.

These are:

- surface water pathway;
- weathered zone pathway; and
- aquifer pathway.

Movement between these pathways is also a potential concern (Ref: GLAL[4]).

2.6 PREMISES

Premises are the information provided by OWMC which have been taken as points of departure for new work. OWMC's basic planning principles and guidelines presented in Section 2.2 are premises

which apply to OWMC's Facility as a whole, including the engineered landfill. The following additional premises have also been used as starting points for landfill concept and feature selection and design in the engineered landfill.

- Whereas the other process areas of the Facility are designed for a particular rate of waste throughput, the landfill must be designed both to accept solidified material at a given production rate and to have the capacity to accept the total quantity of solidified material produced over the active operating life of the landfill.

- The incoming wastes will build steadily to 150 000 t/a by year 5. In the event that incoming wastes continue to build, the Facility will be capable of being expanded to 300 000 t/a with a corresponding increase in solidified material to be landfilled. For the purposes of selecting the landfill concept the 300 000 t/a scenario will be used.

- The three landfill concepts considered in this evaluation process wil be: above-ground, conventional and shallow entombed (Ref: GLAL[3]).

- The treated waste residues will be solidified to form a physically and chemically stable mass following curing in place in the engineered landfill.

- All of the Facility processes; incineration, physical/ chemical treatment, solidification and engineered landfill will be located together on the site.

2.7 POSTULATES

Postulates are assumptions or hypotheses which are basic to the approach used to evaluate alternatives and arrive at an optimum design. The key assumptions, treatment objectives and treatment philosophies which have influenced landfill concepts and features evaluations and design are summarized below:

- Contaminants released from the solidified mass could produce a leachate quality of concern over a period of time measured in hundreds of years (Ref: GLAL[4]).

- The hydrogeologic environment of the site is as identified in Section 2.5 Physical Site Setting and the Geologic, Hydrogeologic and Geotechnical Setting report (Ref: GLAL[5]).

- Engineered devices, that provide for control of contaminant migration from the engineered landfill, will perform their design purposes for a period of time measured in tens of years (Ref: Appendix A).

- Since the life expectancy of devices is much shorter than the time frame expected for release of contaminants, the evaluation of alternatives should include an evaluation of the ability of the natural hydrogeologic setting to control contaminant migration (Ref: GLAL[4]).

- The solidification process used will depend on the solids content of the treated waste residues. High solids material after solidification will have soil-like properties that will allow for transportation by trucking or by conveyor to the

engineered landfill and placement using earth moving equipment. Low solids material will be in a slurry form and will be pumped, by pipeline to the landfill and placed in bermed areas formed using the previously placed high solids material. This material will set in place.

- The quantities of treated residue will vary according to the solids content and quantity of the incoming wastes. The solidified waste quantities resulting from the treated residues will depend on the operating scenario for solidification. The range of solidified material production was defined by two operating scenarios called the "High Solidified Waste Case" and the "High Effluent Case".[1] In addition, an intermediate operating scenario called the "Typical Operations Case" was developed to represent the expected normal production of solidified material.[2] As engineering design progressed in Phase 4B, the "Typical Operations Case" was used to evaluate engineered devices, development method and mode of operation. Finally, the "Typical Operations", "High Solidified Waste" and "High Effluent" solidified waste quantities were used in conceptual design (Chapter 4).

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1. The "High Solidified Waste Case" and "High Effluent Case" represent conservative extremes. In the "High Solidified Waste Case", liquid effluent from the physical/chemical treatment plant is solidified and sent to the landfill. This scenario was previously called Total Solidification. In the "High Effluent Case", excess treated effluent is discharged and residues are solidified prior to disposal in the engineered landfill. This scenario was previously called Partial Solidification (Ref: Monenco Limited[6]).

2. The "Typical Operations Case" was based on waste quantities and characteristics information from similar waste treatment and disposal facilities (Ref: Monenco Limited[6]).

CHAPTER 3
LANDFILL CONCEPT AND FEATURES EVALUATION AND SELECTION

3.1 INTRODUCTION

The previous chapter outlined the framework and environment within which the engineered landfill will operate. The following sections describe the methodology and criteria used to select the landfill concept, engineered devices and development method which are best suited to this particular application. Chapter 3 also summarizes the results and conclusions of the evaluation process including the reasons for either accepting or rejecting each of the alternatives considered.

The main features to be determined in design of an engineered landfill are:

- landfill concept - above-ground, conventional or shallow entombed;
- engineered devices - covers, liners and leachate collection systems;
- mode of operation - active or passive; and
- development method - cell, trench or area.

Chapter 3, Sections 3.5 and 3.6 of this report evaluate the alternatives for these main features.

3.2 METHODOLOGY

The following points summarize the methodology used to evaluate the alternatives considered for the landfill concept and other main features of the engineered landfill.

- Establish the key objectives and philosophies for the proposed engineered landfill (to meet OWMC goals);
- Identify the features required for the engineered landfill;
- Obtain information relating to the materials to be disposed of and the natural hydrogeologic setting of the landfill;
- Establish the framework and criteria for the evaluation and selection of the landfill concept and features;
- Identify the purpose and function of each feature of the engineered landfill;
- Establish suitable alternatives for each feature of the engineered landfill;
- Establish sub-criteria specific to each feature of the engineered landfill based on that feature's role and function;
- Evaluate and rank the relative suitability of each alternative for each feature, and select the preferred alternative for inclusion in the proposed design;
- Design and optimize the resulting engineered landfill system to meet the objectives and philosophies established for OWMC's Facility.

3.3 EVALUATION FRAMEWORK AND CRITERIA SELECTION

A systematic comparative evaluation process was used to evaluate the landfill features. Consistency in the evaluation of each of

the features of the engineered landfill and with previous evaluation procedures was sought. Two technology evaluation procedures had been undertaken previous to the landfill evaluation. A.D. Little and Monenco evaluated technologies for incineration, physical/chemical treatment, solidification and disposal (Ref: A.D. Little[1], Monenco Limited[7,8,9,10]). The evaluation of landfill features is consistent with these previous evaluations where applicable. Adaptations are applied to complement the unique characteristics of the landfill.

Moreso than for other Facility components, landfill performance is dependent on the hydrogeologic setting of the site. Landfill performance, in terms of contaminant control, should be measured for a long period of time (i.e. hundreds of years) rather than for the operating period of the Facility as for the other components. The landfill differs from the other Facility components in that it is a system made up of engineered devices, mode of operation, development method and landfill concept features. The features in the system cannot be evaluated independently of one another.

The criteria developed by Monenco Ltd. are used for evaluation of the landfill features. These are:

- performance
- flexibility
- reliability
- safety
- operational considerations
- economic and commercial considerations
- Canadian benefits.

The sub-criteria developed by Monenco for evaluation of other OWMC Facility components are used as a basis for defining sub-criteria for the comparative evaluation of landfill features.

This list was then compared to objectives developed by A.D. Little to ensure that all of these were incorporated in the final evaluation sub-criteria.

The sub-criteria were applied systematically to evaluate landfill features. A qualitative reasoned argument was developed to support the selection of alternatives. A numerical analysis was not applied as had been the case for Monenco Ltd. and A.D. Little evaluation procedures because broad landfill systems and concepts rather than individual technologies were being evaluated. Strict numerical ratings would not adequately describe these complex features. The significance of the criteria was related to the priorized OWMC goals in a qualitative rather than quantitative manner.

A screening step was included by Monenco and A.D. Little to exclude from the preliminary list, technologies which were unproven or which could not be operated in accordance with current Ontario regulations. The definition of proven technology could not be rigorously applied to the generic landfill concepts considered in the evaluation (Ref: Page 34). This was because landfill performance can only be assessed over a period of tens of years, and there are no known examples of the landfill concepts considered that have been operating and evaluated over this length of time in hydrogeologic settings similar to the site. Therefore, screening based on the proven technology criterion was not feasible. The proven technology screening was applied to evaluate engineered devices and development method options for the preferred concept.

The following describes in detail the selection criteria used in the evaluations.

Performance

This criterion relates to the general performance of the features of the engineered landfill. More specifically it relates to the ability of the features to control the release of contaminants to the environment. This criterion relates to OWMC's goals of minimizing risk to human health and minimizing environmental impact.

Flexibility

This criterion relates to the ability of the landfill features to handle changes in solidified material composition, daily and total volumes, to control leachate migration, and the ability for the landfill concept to be adapted into other concepts. The first two issues relate to the Corporation's third goal of minimizing cost by ensuring flexibility for continuous, efficient operations. All four issues are related to performance and therefore the goals of minimizing risk to human health and minimizing environmental impact.

Reliability

The "reliability" criterion measures the ability of a feature to achieve anticipated results on a consistent basis. This criterion focuses on the physical components of potential features and alternative process systems, the extent of their maintenance requirements, the need for spare parts, the availability of spare parts, the general robustness of the design and its vulnerability to breakdown.

All of these factors influence the reliability of a system and the ability of the Treatment Facility to achieve all three of OWMC's corporate goals.

Safety

Results of evaluation by the "safety" criterion are the most obvious means by which OWMC measures the degree to which a concept or feature achieves its first two corporate goals; to minimize risk to human health and to minimize environmental impact. This criterion is closely linked to the performance criterion.

Operations

Operations play an important role in leachate control and monitoring. This criterion addresses the complexity of operations and hence the potential for operational failures. The potential for off-site effects as a result of operations and the ease of monitoring procedures are also evaluated under this criterion.

Commercial and Economic

This criterion reflects the last of OWMC's corporate goals; the desire to minimize the cost of the Facility and its operation.

Canadian Benefit

Alternative features were examined to determine whether any benefits would accrue to Canada, should one feature be selected over another. This criterion is a measure of the potential positive impacts of the Facility.

3.4 DESCRIPTION OF LANDFILL ALTERNATIVES

3.4.1 INTRODUCTION

The main features of the engineered landfill are identified in Section 3.1 as landfill concepts, engineered devices, development method and mode of operation. Alternative landfill designs are comprised of inputs from each of these.

3.4.2 LANDFILL CONCEPTS

The three landfill concepts to be considered in the evaluation process are: above-ground, conventional and shallow entombed. This is identified as a premise (refer to Section 2.6) to be used as a starting point for concept selection and design of the engineered landfill. The following provides a description of each of the site adapted landfill concepts (see Figure 2):

- Above-Ground - This concept places the solidified material entirely above the ground surface and isolates it from the weathered zone through the use of engineered devices. At the site, an above-ground landfill could be constructed to a height of about 12 m above ground surface based on current geotechnical data (Ref: GLAL[2]). Engineered devices are required to prevent leachate from entering the weathered zone and to prevent leachate springs from occurring at the landfill toe.

- Conventional - This concept places the solidified material both above and below the ground surface. Engineered devices will be necessary to control leachate discharges at the landfill toe and to the weathered zone. Current geotechnical information indicates a total maximum depth of 10 m below grade and a total maximum height of 4 m above grade are possible.

- Shallow Entombed - This concept places all of the solidified material below the base of the weathered zone. A cover thickness of 5 m is recommended (Ref: GLAL[4]). The top surface of the landfill cover will be approximately at the original ground surface level. Engineered devices are not necessary to provide for leachate control and/or collection.

This concept differs from the other two in this regard with significant leachate control available from the natural setting. However, engineered devices could be considered to increase performance and engineering flexibility.

3.4.3 ENGINEERED DEVICES

For each of the landfill concepts, varying forms of engineered devices may be necessary to provide for control of contaminant migration from the landfill. These devices include liners, covers and leachate collection systems. The following provides a description of each of the options for engineered devices.

- Liners - A liner is defined as the engineered device which isolates the landfilled material from the underlying geologic materials and ground water. For the in-ground concepts (conventional and shallow entombed) the liner may be at the base of the landfill only, or on the base and along the in-ground side slopes.

  Three alternatives were considered and evaluated for lining the engineered landfill:

  - Simple liner - this consists of a recompacted clay liner.

  - Complex liner - this included two synthetic barriers and drainage systems.

  - No liner - native clay base - this consists of the native clay as exposed by excavation.

- Covers - The landfill cover is a device placed on top of the solidified mass to isolate the landfilled material from the natural environment. The purpose of the cover is to minimize infiltration to the solidified mass. To achieve this, the

covers are of low permeability (to varying degrees) and graded to direct most of the precipitation to the surface drainage system.

Two cover options were included in the evaluation:

- Simple Cover - The simple cover consists of recompacted native clay material which can be contoured at surface to provide surface water control. As the hydraulic conductivity is dependent on the degree of compaction, a sensitivity analysis of this variable was included in the evaluation.

- Complex Cover - The complex cover uses synthetic barrier layers in the cover.

Leachate Collection Systems - The leachate collection systems which were considered for use with landfill concepts are: i) a perimeter drain system and ii) an underdrain system. A description of each of these follows:

- Perimeter Drain System - This is a ground water collection device installed beyond or at the limit of the landfilling area. For the above-ground or conventional landfill concepts, this can be installed at the toe of the landfill. For the shallow entombed landfill it can be installed around the perimeter of the landfill area. Drainage can be accomplished by pumping from a sump that is gravity fed from the perimeter drain system.

- Underdrain System - This generally consists of a highly permeable granular layer or synthetic drainage net at the bottom and side slopes (where applicable) of the landfill.

Drainage can be accomplished by pumping from a piping system or from a sump that is gravity fed from the underdrain system, to Treatment Facility components (i.e. incineration, physical/chemical treatment).

The leachate collection systems noted above each require active operation in order to fulfill their function. A passive mode in which the leachate collection system is not operated was also considered for the shallow entombed landfill concept.

3.4.4 DEVELOPMENT METHOD

Development methods considered during the evaluation process include cell, trench and area methods.

A description of each of the development methods is outlined below:

- Cell - The cell development method provides discrete cells (each with capacity for six months production of solidified material[1]) for depositing solidified material. Each cell is constructed, filled and closed as a unit. For a given development method, cells may have the configuration of the above-ground, conventional or shallow entombed landfill concept.

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1. Assuming 300 000 t/a incoming waste.

- Trench - The trench method of development is similar to cell development; however, the cell lengths are limited only by landfilling area constraints. Unlike cells, the trenches are operated continuously with the construction and filling operations advancing together. Any engineered devices are extended as the operations advance, rather than being completed in one unit as in the cell method of development.

- Area - The area method is limited only by the area available for landfilling. The landfill is developed over the full area available. As with the trench method, the operations are continuous with construction and filling advancing together. Engineered devices are extended as the operations advance.

3.5 EVALUATION OF LANDFILL CONCEPTS

3.5.1 INTRODUCTION

In this section, the landfill concepts described in Section 3.4.2 are evaluated based on the criteria identified in Section 3.3.

3.5.2 METHODOLOGY

Figure 4 outlines the methodology used to evaluate the landfill concepts. In the first step of the comparative evaluation, assumptions were established regarding engineered devices. The concepts were then compared based upon evaluation criteria and sub-criteria. The proposed landfill concept was the outcome of this step.

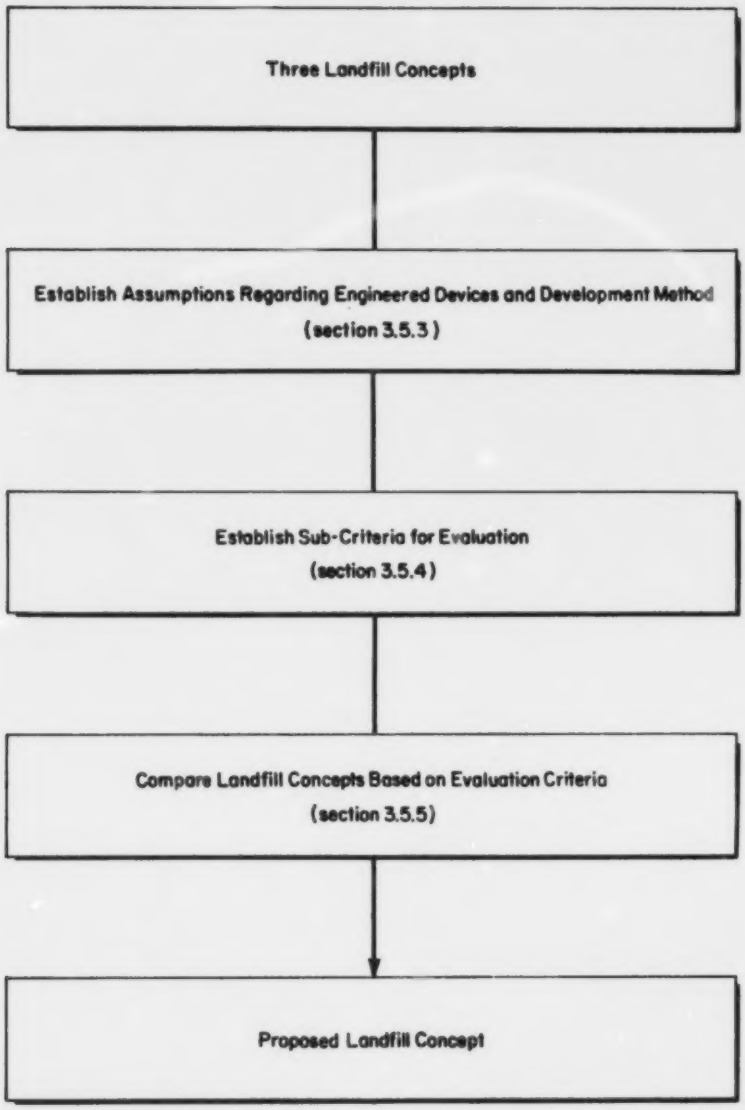

Figure 4

METHODOLOGY USED IN COMPARATIVE EVALUATION OF LANDFILL CONCEPTS

3.5.3 ESTABLISHMENT OF ASSUMPTIONS REGARDING ENGINEERED DEVICES AND DEVELOPMENT METHOD

As mentioned in Section 2.7, for the purpose of evaluating hydrogeologic performance of the landfill concepts, it was assumed that any engineered devices included in the landfill (i.e. cover, liner, leachate collection system) will likely fail in a time frame measured in tens of years.[1] Therefore, for the purpose of evaluating long-term hydrogeologic performance, non- repairable devices were assumed to fail (i.e. equivalent to no devices).

The cell development method was assumed for this evaluation. It was selected to be consistent with earlier evaluations.

Assumptions regarding engineered devices are required to compare the concepts on the basis of other engineering considerations such as flexibility, operations and cost. The assumptions were developed based on the following:

- compatible devices are grouped into systems;
- the devices complement the requirements for each landfill concept; and
- the devices are practical.

Figure 5 lists the devices assumed for the purpose of evaluating the landfill concepts (Ref: GLAL[4]).

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1. Appendix A contains a literature review regarding service life for engineered devices. The findings of this review support the postulate that ultimately engineered devices will fail.

COVER SYSTEM	
Above-Ground	Complex
Conventional	Complex
Shallow Entombed	Simple

LINER SYSTEM	
Above-Ground	Required
Conventional	Optional (not required)
Shallow Entombed	Not Required

LEACHATE COLLECTION SYSTEM	
Above-Ground	Underdrain System
Conventional	Perimeter Drain System
Shallow Entombed	Not Required

LEACHATE SYSTEM OPERATION	
Above-Ground	Active
Conventional	Active
Shallow Entombed	Passive

METHOD OF DEVELOPMENT	
All Concepts	Cell

Figure 5

LANDFILL DESIGN AND OPERATION ASSUMPTIONS FOR EVALUATION OF LANDFILL CONCEPTS

The following describes the rationale for each assumption based on the requirements for each concept:

- Above-Ground Concept - This concept relies totally on engineered devices for control of leachate migration to the environment. The hydrogeologic setting of the site is important, however, in that it affords protection to the aquifer in case of failure of the engineered devices. A complex cover system is required to minimize infiltration of precipitation or surface runoff into the waste, thereby minimizing leachate production and the quantities to be collected to prevent leachate breakout. A complex liner system is required to control leachate migration to the surface or near surface environment because the weathered zone upon which the landfill sits provides little control. To reduce the head of leachate over the liner and thereby control leachate migration and the generation of leachate springs at the landfill toe, an underdrain has been assumed.

- Conventional Concept - This concept relies partly on the landfill hydrogeologic setting to provide control of leachate migration. The complex cover is required for the same purpose as in the above-ground concept. The leachate produced will tend to mound above existing ground surface unless controlled. To prevent surficial seeps of leachate and reduce the height of leachate in the landfill, a perimeter drain is required.

  Depending on the hydrogeologic setting, the liner system could be simple or complex. For the site, the hydrogeologic setting can be expected to provide good leachate control, therefore a simple liner has been assumed.

- Shallow Entombed Concept - The concept relies on the natural hydrogeologic setting to the greatest extent of the three concepts to provide control of leachate migration.

  The hydrogeologic setting at the site is such that a simple liner can be assumed. Since the solidified mass is buried below the weathered zone, migration of leachate through the weathered zone and to surface will be by diffusion and therefore will be very slow if it occurs at all. Therefore no leachate collection system has been assumed. Since leachate production, after the solidified mass has become saturated, is controlled by the hydraulic conductivity of the soil beneath the landfill which is very low, a simple soil cover has been assumed.

3.5.4 ESTABLISHMENT OF SUB-CRITERIA FOR EVALUATION

The sub-criteria reflect specific objectives identified under each criterion that will be used to identify differences between the alternatives being evaluated. The sub-criteria are similar to those developed by Monenco for use in evaluating technologies for the other process areas. They have been modified to reflect the objectives of each of the major features of the engineered landfill. Some sub-criteria included in the list may be inapplicable to the engineered landfill.

The sub-criteria used for evaluation of landfill concepts (with their assumed devices) are identified and described as follows:

o **PERFORMANCE**

- Disruption of natural surface and groundwater systems
- Contaminant transport time to underlying aquifer
- Potential for offsite contamination resulting from lateral fracture zone flow
- Potential for direct surface water contamination.

)Developed by GLAL and documented in their report Ref: GLAL[4]

- Efficiency of Land Use - This relates to the capacity to receive solidified material developed by each concept in a given land area.

- Leachate Produced - This relates to the quantities of leachate produced for each concept. A lower quantity of leachate is preferred because the aim of the landfill concept is to achieve the lowest rate of leachate migration in the long-term.

- The criterion "proven technology"[1] was applied by Monenco to evaluate the other facility components. The purpose was to avoid known or yet undiscovered problems with technology options. The ability of a landfill to control contaminant release can only be measured over tens of years. No known examples of the landfill concepts considered have been operating and evaluated for this length of time in

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1. Defined as those technologies which have been commercially demonstrated to perform reliably for a period of at least 12 months on a scale and in a manner comparable with that required for the OWMC facility.

hydrogeologic settings similar to the site. Therefore, the criterion "proven technology" could not be applied to landfill concepts. However, the intent of the criterion was to protect human health and the environment over the life of the Facility. This is covered by the performance criterion for the landfill concepts.

- Long-Term Maintenance Requirements - This relates to the level of maintenance required for control of contaminant migration during the closure and post-closure period.

o **FLEXIBILITY**

- Design Flexibility - Design flexibility is the ability of the Facility to function under changing conditions to ensure constant ability to treat incoming waste quantities.
  - Concepts - This relates to the ability to start with one concept and subsequently modify to another concept.
  - Devices - A larger number of alternatives available for consideration increases flexibility.
  - Operations - Devices that can be operated actively and passively are more flexible.

- Sensitivity to Changes in Feed Rate - Related to ability to adjust to increases in materials requiring landfill disposal.

- Turndown - Relates to the ability to operate at partial loads which ensures ability to maintain effective disposal under changing conditions.

- Site After Use Potential - Related to the landform created and its potential to be used for other purposes at some point in the post-closure period. This relates to the goal of minimizing environmental impact.

o **RELIABILITY**

- Regular Maintenance Requirements (during operations) - Relates to the complexity of the devices and their operating mode. Lower maintenance and higher reliability increases potential for devices to protect human health and the environment.

- Spares - The need for, and availability of, spares affects reliability and hence ability of devices to protect human health and the environment.
  - Requirement - Relates to the complexity and nature of the devices.
  - Availability - Relates to the sophistication of the devices and how readily spare components can be available.

- Robustness - Relates to the complexity and sophistication of the devices and hence their ruggedness and durability. More complex and sophisticated devices are usually less rugged and durable.

- Vulnerability to Interruption of Operations - How critical short-term interruption is to the performance of the concepts and how likely it is to be interrupted.

o **SAFETY**

- Occupational Risk During Normal or Upset Conditions - The potential health effects from working in the landfill.

- Environmental Risk on Upset Conditions - Short-term event related to risk to the environment.

o **OPERATIONS**

- Complexity of Process - Related to the complexity of devices and level of maintenance required during the operating life of the Facility. Higher complexity is less desirable because of higher potential for failures in operations.

- Off-site Effects
  - Clay Export - Relates to the quantities of clay material that would have to be imported to the site or exported from the site, by truck, due to landfill development. Import and export of clay have associated impacts.
  - Visual - Relates to the height of the landform created by land-filling. Visual impacts are greater with increased height.
  - Filling Operations - Relates to the amount of noise, dust and odours occurring during operations that may affect the surrounding community.

- Ease of Monitoring - The ability to monitor the contaminant control performance of the concept is considered a benefit because it provides greater assurance of protection of human health and the environment.

- **COMMERCIAL AND ECONOMIC**

  - Capital - initial landfill development costs.

  - Operations - The operating costs during the active operating period of the Facility.

  - Closure - The costs associated with maintenance, monitoring, repair, operation of devices after completion of landfilling and prior to post-closure.

  - Post-Closure - Same as closure but during the post-closure period.

- **CANADIAN BENEFITS**

  - Benefits - measure of any potential positive impacts of the Facility between alternatives.

3.5.5 COMPARISON OF LANDFILL CONCEPTS BASED ON EVALUATION CRITERIA

Table 1 provides a rating for each evaluation sub-criterion in each landfill concept. The ratings for the sub-criteria were developed by scaling the results into three levels (high, intermediate and low). Subjective judgements were applied to develop ratings for sub-criteria. Table B-1 in Appendix B provides the rationale for the ratings in each sub-criterion.

TABLE 1

COMPARATIVE EVALUATION OF LANDFILL CONCEPTS

CRITERIA	SUB-CRITERIA	ABOVE-GROUND	CONVENTIONAL	SHALLOW ENTOMBED	REMARKS
PERFORMANCE	• DISRUPTION OF NATURAL SURFACE AND GROUND WATER SYSTEMS	HIGH	HIGH	LOW*	SHALLOW ENTOMBED CONCEPT MOST CLOSELY RESEMBLES NATURAL SETTING
	• IMPACT ON GROUND WATER FLOW	HIGH	INTERMEDIATE	LOW*	
	• CONTAMINANT TRANSPORT TIME TO UNDERLYING AQUIFER	LONG	LONG	LONG	
	• POTENTIAL FOR OFF-SITE CONTAMINATION RESULTING FROM LATERAL WEATHERED ZONE FLOW	HIGH	HIGH	LOW*	FOR SHALLOW ENTOMBED CONCEPT UPWARD DIFFUSION RATES LOW RELATIVE TO DIRECT LEACHATE FLOW FROM OTHER CONCEPT.
	• POTENTIAL FOR DIRECT SURFACE WATER CONTAMINATION	HIGH	HIGH	LOW*	"MOUND EFFECT" EXPECTED FOR ABOVE-GROUND AND CONVENTIONAL CONCEPTS
	• EFFICIENCY OF LAND USE	LOW	HIGH*	LOW	
	• LEACHATE PRODUCED	HIGH	HIGH	LOW*	INSUFFICIENT DATA TO DETERMINE TREATMENT REQUIREMENTS.
	• PROVEN TECHNOLOGY	-	-	-	DEFINITION OF PROVEN TECHNOLOGY NOT APPLICABLE TO LANDFILL
	• LONG-TERM MAINTENANCE REQUIREMENTS	HIGH	INTERMEDIATE	LOW*	
FLEXIBILITY	• DESIGN FLEXIBILITY				
	- CONCEPTS	LOW	LOW	INTERMEDIATE*	SHALLOW ENTOMBED COULD BE CONVERTED TO CONVENTIONAL PENDING LONG TERM MONITORING RESULTS
	- DEVICES	LOW	INTERMEDIATE	HIGH*	MINIMUM REQUIREMENTS ARE A PERIMETER DRAIN FOR CONVENTIONAL: AND LINER AND UNDERDRAINS FOR ABOVE-GROUND
	- OPERATIONS	LOW	INTERMEDIATE	HIGH*	ABOVE-GROUND CONCEPT REQUIRES ACTIVE OPERATION
	• SENSITIVITY TO CHANGES IN FEED RATE	INTERMEDIATE	INTERMEDIATE	INTERMEDIATE	
	• SENSITIVITY TO CHANGES IN FEED COMPOSITION	INTERMEDIATE	INTERMEDIATE	LOW*	SHALLOW ENTOMBED IS A COMPLETELY BELOW GROUND OPERATION.
	• TURNDOWN	-	-	-	ALL CONCEPTS JUDGED TO BE EQUAL
	• SITE AFTER USE POTENTIAL	LOW	LOW	INTERMEDIATE*	SHALLOW ENTOMBED RESULTS IN MINIMAL LONG TERM CHANGES TO TOPOGRAPHY

* Indicates best rating for sub-criterion.

TABLE 1

COMPARATIVE EVALUATION OF LANDFILL CONCEPTS (CONTINUED)

CRITERIA	SUB-CRITERIA	ABOVE-GROUND	CONVENTIONAL	SHALLOW-ENTOMBED	REMARKS
RELIABILITY	• REGULAR MAINTENANCE REQUIREMENTS (DURING OPERATIONS)	HIGH	INTERMEDIATE	LOW*	SHALLOW ENTOMBED CAN HAVE PASSIVELY OPERATED LEACHATE SYSTEM AND NO ABOVE GROUND SLOPES TO PROTECT
	• SPARES				
	- REQUIREMENT	HIGH	INTERMEDIATE	LOW*	
	- AVAILABILITY	HIGH	HIGH	HIGH	
	• ROBUSTNESS	LOW	INTERMEDIATE	HIGH*	SHALLOW ENTOMBED IS COMPLETELY IN GROUND AND MAY NOT BE DEPENDENT ON SYNTHETIC OR ENGINEERED DEVICES
	• VULNERABILITY TO INTERRUPTION OF OPERATIONS	LOW	LOW	LOW	
SAFETY	• OCCUPATIONAL RISK DURING NORMAL OR UPSET CONDITIONS	LOW	LOW	LOW	
	• ENVIRONMENTAL RISK ON UPSET CONDITIONS	LOW	LOW	LOW	
OPERATIONS	• COMPLEXITY OF PROCESS	HIGH	INTERMEDIATE	LOW*	SHALLOW ENTOMBED HAS LOWEST MAINTENANCE REQUIREMENTS AND LEAST COMPLICATED DEVICES
	• OFF-SITE EFFECTS				
	- CLAY MATERIAL IMPORT/EXPORT	LOW*	INTERMEDIATE	HIGH	ABOVE-GROUND HAS LOWEST VEHICULAR REQUIREMENT FOR CLAY IMPORT/EXPORT
	- VISUAL	-	-	-	
	- FILLING OPERATIONS				
	- NOISE	-	-	-	
	- DUST	-	-	-	
	- ODOUR	-	-	-	
	• EASE OF MONITORING				
	- PERFORMANCE	INTERMEDIATE	INTERMEDIATE	INTERMEDIATE	
	- ENVIRONMENTAL	INTERMEDIATE	INTERMEDIATE	INTERMEDIATE	
COMMERCIAL AND ECONOMIC	• CAPITAL	HIGH	LOW*	INTERMEDIATE	
	• OPERATIONS	HIGH	LOW*	INTERMEDIATE	
	• CLOSURE	HIGH	INTERMEDIATE	LOW*	
	• POST-CLOSURE	HIGH	INTERMEDIATE	LOW*	
CANADIAN BENEFIT		-	-	-	DIFFERENCE UNKNOWN AT THIS TIME

* Indicates best rating for sub-criterion.

A review of Table 1, Comparative Evaluation of Landfill Concepts, indicates that the shallow entombed landfill concept has the best rating for all criteria and sub-criteria with the following exceptions:

- Performance - efficiency of land use;
- Off-Site Effects - clay material import/export;
- Commercial and economic - capital
  - operations

Each of the above sub-criteria not favouring the shallow entombed concept is discussed below. These sub-criteria are then balanced against those remaining criteria that favour the shallow entombed concept. This evaluation process results in shallow entombed as the proposed landfill concept.

Criteria for Which Shallow Entombed is Not the Preferred Concept

a) Performance - Efficiency of Land Use

Table 2 indicates the landfill lives for each landfill concept under various assumptions with regard to the solidification options, design parameters (e.g. side slopes), development method and solidified material inflow volumes.

The assumptions used have a large effect on the potential landfill capacity. For site selection purposes, 300 000 tonnes per year peak incoming waste at year 10 was assumed as the worst case for impact assessment. If a peak of only 150 000 tonnes per year in year 5 were realized, the life of the landfill would increase between 25 and 85 percent. The second factor is the solidification option used. The options used in the Phase 4A site selection process are total solidification and partial solidification with evaporation applied as a sensivity analysis. In the

TABLE 2

LANDFILL LIVES FOR LANDFILL CONCEPT ALTERNATIVES (YEARS)

LANDFILL TYPE	TOTAL SOLIDIFICATION				PARTIAL SOLIDIFICATION			
	CELL METHOD		TRENCH+ METHOD	AREA+ METHOD	CELL METHOD		TRENCH+ METHOD	AREA+ METHOD
	3:1* (in ground)	2:1* (in ground)			3:1* (in ground)	2:1* (in ground)		
Above-Ground	11 (14)		12 (18)	16 (25)	17 (23)		23 (38)	31 (57)
Conventional	14	17 (25)	20 (30)	22 (37)	24	30 (37)	40 (72)	45 (83)
Shallow Entombed	9	11 (14)	13 (19)	19 (31)	13	18 (21)	24 (41)	38 (68)

NOTE:

Site lives based on a waste inflow of 300 000 t/a with numbers in brackets based on an inflow rate of 150 000 t/a.

* Refers to in-ground side slopes.
\+ Based on 2:1 in-ground side slopes.

present comparison, total solidification and partial solidification with evaporation are used as a bracketing range to view landfill capacity.[1] Landfill capacity is increased substantially when partial solidification rather than total is used. The development method also affects capacity. The cell method has the lowest landfill lives and the area method has the longest for all landfill concepts.

Conventional landfill has the greatest site lives for all the conditions evaluated on Table 2. Site lives for above-ground and shallow entombed are smaller and of similar magnitude. While conventional landfill has the highest rating for efficiency of land use, the significance of this criterion is diminished because of the alternative development methods and solidification scenarios available for mitigation. As an example, for the shallow entombed landfill, site lives over 20 years can be achieved with partial solidification for both trench and area methods (24 and 38 years respectively). Therefore, with optimization, any of the landfill concepts should provide a reasonable site life.

b) <u>Operations: Off-Site Effects - Clay Material Import/Export</u>

For above-ground landfill, there is no excavation. Therefore the materials for cover and berming must be imported. The conventional and shallow entombed concepts generate more excavated clay on-site than is required for final cover or berm construction. This clay must be disposed of either on-site or off-site.

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1. This assumption was selected to cover the minimum and maximum capacity requirements for the landfill concepts at the time of the evaluation. These cases have now been superseded by the "Typical Operations", "High Solidified Waste" and "High Effluent" scenarios (Ref: Monenco Limited[6]).

Appendix C contains a review of the requirements for either trucking excess clay material off-site for conventional and shallow entombed concepts, or importing clay from off-site for the above-ground concept. The review contains details of import and export requirements, the off-site locations available for either disposal or import of material, a review of the truck fleet requirements for transport of clay and operating costs information.

Table 3 lists the volume of material imported or exported, truck trips and haulage costs. Based on these factors, the above-ground concept has the lowest volume of material imported and exported, lowest truck trips and costs. Shallow entombed and conventional are similar, although material volumes, truck trips, and costs are higher for the shallow entombed concept.

c) **Commercial and Economic - Capital and Operating Costs**

Table 4 contains capital and operating costs for the three landfill concepts based on partial and total solidification. Conventional landfill has the lowest costs and above-ground has the highest. The difference in costs are approximately 10% to 24% for capital costs and 18% for operating costs between conventional and shallow entombed concepts. This represents a maximum difference of approximately $1,000,000 in capital costs and $1,000,000 in annual operating costs at year 10.

Criteria For Which Shallow Entombed is the Best Rated Concept

The benefits associated with the shallow entombed landfill concept are discussed in the following paragraphs.

The shallow entombed landfill concept is best rated with regard to the performance criterion (with the exception of efficiency of land use). This criterion directly relates to the most highly ranked goals of OWMC - to minimize risk to human health and minimize environmental impact (see Section 2.2).

TABLE 3

CONSIDERATIONS IN CLAY MATERIAL IMPORT/EXPORT

CONSIDERATIONS	LANDFILL CONCEPT: Shallow Entombed — Maximum Material[7]	Shallow Entombed — Minimum Material[8]	Conventional — Maximum Material[7]	Conventional — Minimum Material[8]	Above-Ground[1] — Maximum Material[7]	Above-Ground[1] — Minimum Material[8]
• Treatment Option:	Total Solid.	Part.Solid.	Total Solid.	Part.Solid.	Total Solid.	Part.Solid.
• Disposal Method:	Area Method	Trench Method	Area Method	Cell Method	Cell Method	Area Method
• Bulked Up Annual Volume of of Material[2] (m^3)	379,000	147,000	307,000	109,000	74,000	22,000
• Annual Truck Trips[3] (one-way)	27,072	10,501	21,929	7,786	5,286	1,572
• Daily Truck Trips[4] (one-way)	109	43	88	32	22	7
• Avg.Haulage[5]:						
- annual cost ($ x 10^6)	3.09	1.20	2.50	0.89	0.67	0.20
- fleet size[6]	22	9	18	6	5	2

Notes:
1. Material for above-ground will be imported.
2. 15% bulking factor
3. Assume 14 cubic metre capacity semi dump trucks (5 axle).
4. Assume 250 working days/year.
5. Average haulage cost and fleet size based on average distance from landfill to the site material source/deposit site clusters.
6. Assume 8 hour working days; does not include spares.
7. Maximum material volume is for final year of landfill life.
8. Minimum material volume is for year 10 of landfill life.

LANDFILL DEVELOPMENT COSTS

COSTS IN (x$1,000)

ITEM	LANDFILL TYPE: Above-Ground Total	Above-Ground Partial	Conventional Total	Conventional Partial	Shallow Entombed Total	Shallow Entombed Partial
CAPITAL COSTS						
- Clearing and grubbing	85	85	85	85	85	85
- Redirect existing watercourses	-	-	-	-	-	-
- Excavation (cell, contaminated water storage pond, detention pond, access roads, perimeter ditches, berms and temporary pot. cont. storage pond).	403	378	717	519	1,465	800
- Lining (cell)	416	208	-	-	-	-
- Lining (contaminated water storage pond)	156	78	65	32	-	-
- Granular lining (cell)	480	240	-	-	-	-
- Leachate collection system	327	281	293	238	-	-
- Leachate collection system to plant or leachate loading facility	58	58	58	58	-	-
- Access roads	126	126	126	126	126	126
- Seeding	145	52	126	38	145	52
- Security fence	285	285	285	285	285	285
- Lighting	25	25	25	25	25	25
- Administration building	-	-	-	-	-	-
- Equipment storage and maintenance building	-	-	-	-	-	-
- Parking area	-	-	-	-	-	-
- Equipment initial purchase	1,154	1,154	1,154	1,154	1,154	1,154
- Cell monitoring	10	10	10	10	10	10
- Land acquisition[1]	930	330	247	-	930	330
TOTAL	4,600	3,310	3,191	2,570	4,225	2,867
ANNUAL OPERATING COSTS YEAR 10 (ACTIVE FACILITY OPERATING PERIOD)						
- Construction of two cells (excavation, liner, leachate collection system in cells and cover on complete cells including import or export of clay)	4,375	2,232	2,923	1,328	3,875	1,905
- Extend delivery system (pipe & conveyor plant to cells	30	30	30	30	30	30
- Operation and maintenance of equipment	188	140	188	140	188	140
Site maintenance	151	151	151	151	50	50
- Utilities	12	6	12	6	12	6
- Manpower	469	344	469	344	469	344
- Performance monitoring	20	20	20	20	20	
TOTAL	5,245	2,923	3,793	2,019	4,644	2,495

1. Land acquisition cost added to balance cost figures based on common landfill life.

To more fully understand the evaluation of the landfill concepts based on performance, the hydrogeologic assumptions and their implications for the evaluation of the landfill concepts are reiterated.

1) Engineered devices (covers, liners and leachate collection systems) will likely fail in a time frame measured in tens of years.

2) Leachate of a quality of concern could be generated in a time frame measured in hundreds of years.

Therefore:

3) The natural hydrogeologic setting will have to be relied upon to restrict contaminant movement in the long-term.

4) Comparison of the landfill design concepts is based on a passive operational mode equivalent to failure of the engineered devices.

Figure 6 shows schematically the impact that each of the landfill concepts would have on the ground and surface water systems at the site. This is based on the results of a generic modelling exercise conducted by Gartner Lee Associates Limited. (Ref: GLAL[4]).

Disruption to ground and surface water is lowest for the shallow entombed concept. For all concepts, the water table is expected to rise up to near the surface of the landfill. For above-ground and conventional concepts the resulting ground water mound will result in surficial leachate seeps and greater rates of leachate migration in the ground water system (relative to the

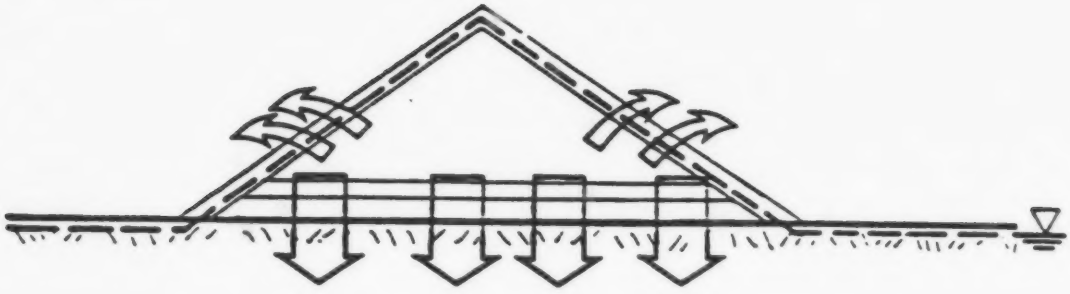
natural rate of ground water flow at the site). The leachate rate of migration from the shallow entombed concept is comparable to the natural rate of ground water flow at the site. The shallow entombed concept places all waste below the weathered zone, so that the weathered zone and surface water would only be contaminated by upward flow (not expected) or by upward diffusion. This is in contrast to the other concepts that will allow direct contact with the weathered zone and surface water assuming that devices fail (see hydrogeologic assumptions). The modelling conducted by Gartner Lee Associates Limited supports these predictions (Ref: GLAL[4]).

Relative to the above-ground and conventional concepts, the amount of leachate produced will be smaller for the shallow entombed concept. The amount of precipitation that can enter the landfill is controlled by the low hydraulic conductivity of the underlying geologic materials. Shallow entombed has little effect on the ground water table and therefore does not produce an increased hydraulic gradient. Also, the shallow entombed concept minimizes the amount of leachate entering surface water and weathered zone pathways.

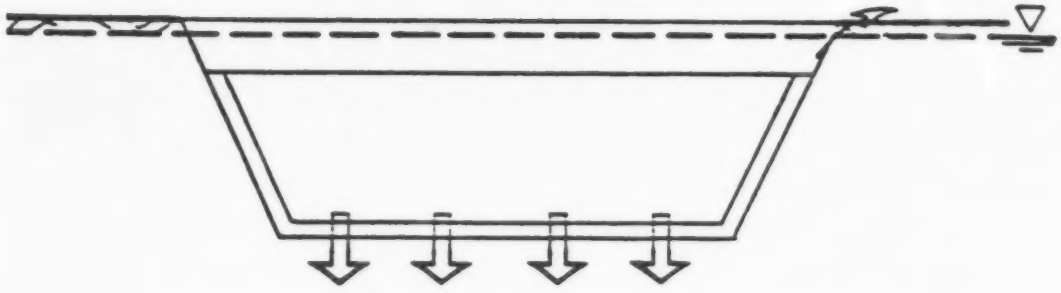
The shallow entombed concept also has high natural containment. Contaminant transport time to underlying aquifer is expected to be long for all concepts (800 to 1200 years) (Ref: GLAL[4]).

Based on the hydrogeologic performance sub-criteria, the shallow entombed landfill concept is preferred. Potential for ground and surface water contamination is lowest for this option and natural containment time is long.

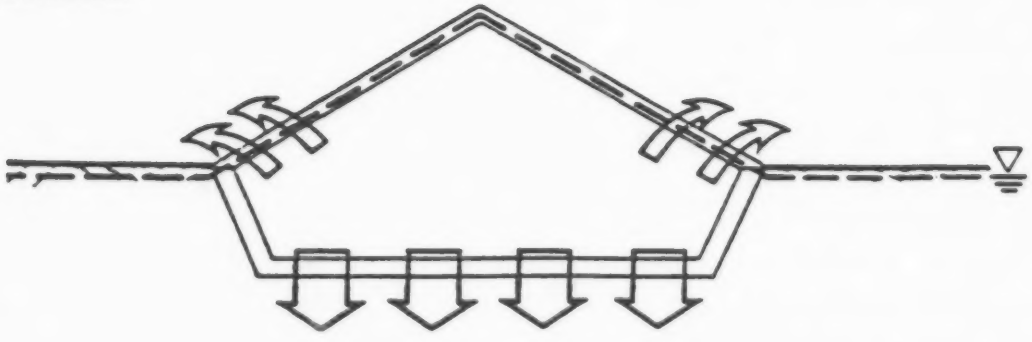
1. Above-Ground



2. Shallow Entombed



3. Conventional



Not to Scale

Figure 6
ALTERNATIVE LANDFILL CONCEPTS
POTENTIAL HYDROGEOLOGIC PERFORMANCE

Source: Gartner Lee Associates Limited, 1986

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Environmental Scientists

In addition to high performance, the shallow entombed concept provides the greatest design flexibility and potential for limited reliance on engineered devices to ensure long-term performance. However, engineered devices can be added as contingency measures or to increase performance during the lifetime of the engineered devices (e.g. perimeter drain). The shallow entombed concept has potential to be converted to the conventional concept by removing the cover and increasing the fill height of the solidified mass above grade. This option could be considered if additional landfill capacity were necessary and monitoring determined that leachate is of acceptable quality. The flexibility of the shallow entombed concept increases opportunities to ensure adequate control of leachate.

The shallow entombed concept is also preferred with regard to reliability and operations. The shallow entombed concept can have a passively operated leachate collection system and has no above ground slopes to maintain. A perimeter drain can be added which will require continued maintenance. The lack of dependence on engineered devices reduces maintenance requirements, requirements for spares, the complexity of the design and degree of automation. The system is consequently more reliable and has lower operating requirements.

The commercial and economic criterion does not favour the shallow entombed concept if viewed only on the basis of operating costs during the landfill life. However, the costs of maintenance and monitoring of the shallow entombed concept are lower than the other concepts during the period after active operation (i.e. closure and post-closure periods). As a result, the overall cost differences between the concepts are reduced. In addition, the differences in cost do not represent a large proportion of the total Facility operating costs. Similarly, the higher costs for

export of clay for shallow entombment under the off-site effects criterion are not considered to be as significant as hydrogeologic performance and operational flexibility based on the ranking of OWMC goals.

The off-site impacts of clay export are also higher for shallow entombed. This has been evaluated by the site assessment consultants.

Finally, the lower landfill life for the shallow entombed concept is acceptable because landfill lives of twenty years or more are possible for area and trench development methods depending on the solidification option chosen.

The criteria favouring shallow entombment outweigh those favouring other landfill concepts. The criteria favouring shallow entombment relate to the OWMC goals of minimizing risk to human health and minimizing environmental impact. The hydrogeologic performance, operational flexibility and operations for shallow entombment show that it has the greatest capability to control contaminants in the short and long-term with little or no reliance on engineered devices.

3.6 EVALUATION OF REMAINING LANDFILL FEATURES

3.6.1 INTRODUCTION

The purpose of engineered devices for the landfill is to control leachate production and migration to the environment. As mentioned previously (Ref: Page 17), devices will likely fail within a period of time measured in tens of years. This is a much

shorter period of time than the time frame expected for release of contaminants (hundreds of years). Therefore the natural environment must be relied on for long-term leachate control. The shallow entombed landfill optimizes this control for the site.

It can be argued that engineered devices are unnecessary for the shallow entombed concept because long-term performance is of greater significance than short-term performance in the passage of time. However, a system of devices provides a greater certainty in the short-term that risks to human health and the environment will be minimized. Devices also have the flexibility to be left in the passive mode or be operated actively (as a contingency measure). This flexibility is not provided by the natural environment. Therefore, it is prudent to consider systems of devices to augment the natural hydrogeologic setting control of leachate.

In this section, engineered devices, development method and mode of operation are evaluated. These features are discussed in Sections 3.4.3 and 3.4.4. This section establishes the system of devices, mode of operation and development method that will be used as a starting point, along with the shallow entombed concept selected in Section 3.5, for conceptual landfill design as described in Chapter 4.0.

3.6.2 METHODOLOGY

Figure 7 outlines the methodology used to evaluate the engineered devices, development method and mode of operation options.

In the first step, the devices are structured into three systems that incorporate the landfill concept, compatible engineered devices, cell development method and one operating mode (active or passive). As well the concept was placed in the

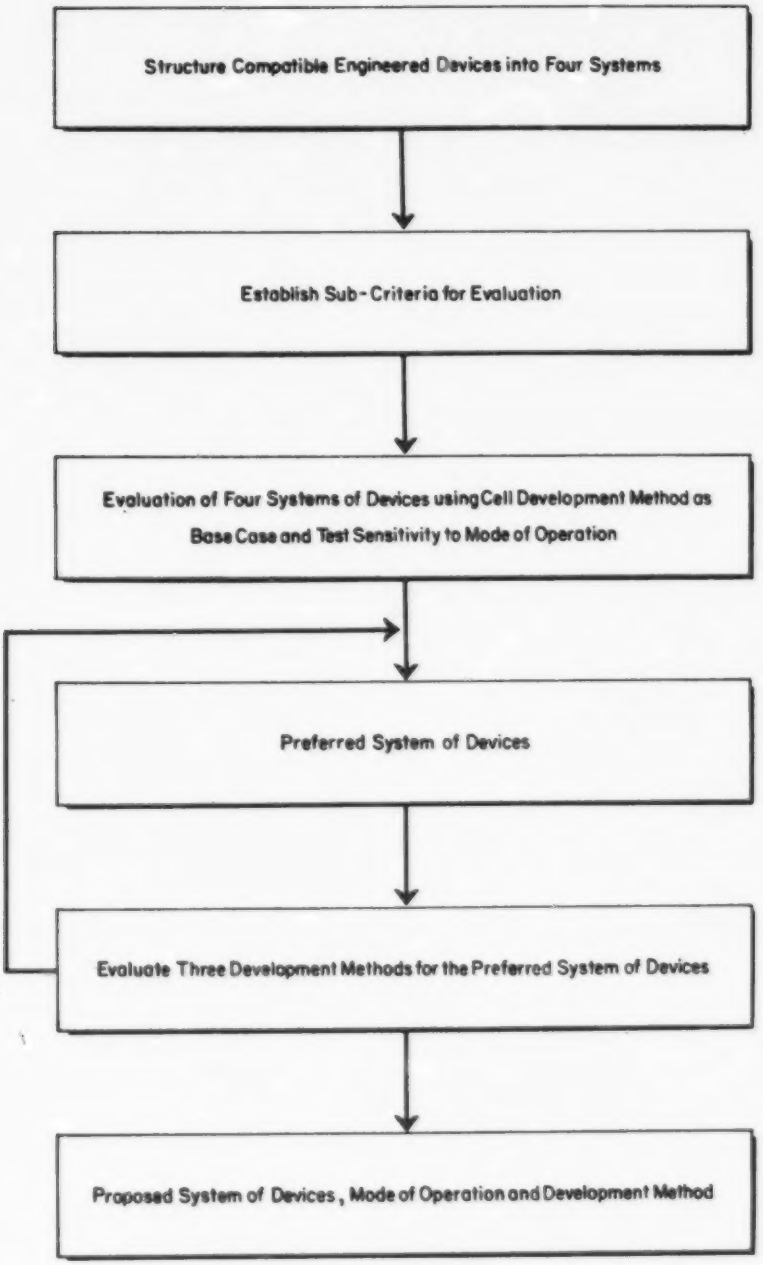

Structure Compatible Engineered Devices into Four Systems
Establish Sub-Criteria for Evaluation
Evaluation of Four Systems of Devices using Cell Development Method as Base Case and Test Sensitivity to Mode of Operation
Preferred System of Devices
Evaluate Three Development Methods for the Preferred System of Devices
Proposed System of Devices, Mode of Operation and Development Method

Figure 7

METHODOLOGY USED IN THE EVALUATION OF SYSTEMS OF DEVICES, MODE OF OPERATION AND DEVELOPMENT METHOD

natural hydrogeologic setting. This option (Base Case) was used as a point of comparison. In the second step, sub-criteria were developed for each of the main criteria discussed in Section 3.3. In the third step, the three selected systems of devices were evaluated against the Base Case, and a preferred system was identified. A sensitivity analysis was then undertaken to test the preferred system with regard to mode of operation. The output from this step was a preferred system. The fourth step was the evaluation of the three development methods using the preferred system from step three. This step or, loop back, tested the sensitivity of the development method to the preferred system. The output from this step was a preferred development method. The output from this final step was the overall proposal regarding the system of devices, mode of operation and development method.

3.6.3 DEVELOPMENT OF SYSTEMS OF DEVICES

The landfill devices were not evaluated independently because the devices work as an integral part of the landfill concept. Therefore combinations of devices were developed. The alternative systems of devices considered were developed based on the following:

- the devices were compatible with the proposed landfill concept (shallow entombed);
- compatibility among the devices in the system for control of leachate production and migration;
- represent a range of both long and short-term performance;
- represent a range of alternatives for evaluation; and
- represent active operation of the leachate control systems to determine the best potential performances of the systems.

With regard to the first point, the rationale for selection of the shallow entombed concept is contained in Section 3.5. In summary, the shallow entombed landfill concept affords the best long-term performance because it best segregates the waste from the weathered zone flow systems and is least disruptive of natural conditions thereby minimizing the potential for interaction between the waste and the weathered zone flow systems. The other two concepts set up artificial gradients - this complements the natural conditions. No dependence on engineered devices is required for this concept but devices can be included to increase operating flexibility and performance.

Compatibility among the devices is based on Gartner Lee Associates Limited's evaluation of the performance of individual and grouped engineering devices (Ref: GLAL[4]). This information was built into the development of systems of devices to ensure they were complementary for leachate control.

With regard to the third point, long and short-term performance, a literature review (see Appendix A) established that the control of leachate by devices will work only over the short-term (i.e. devices will fail). The literature review with regard to service life for devices, also found that the useable life of devices can be made indefinite only where repair or replacement are possible. Therefore, the device systems considered include repairable and non-repairable devices.

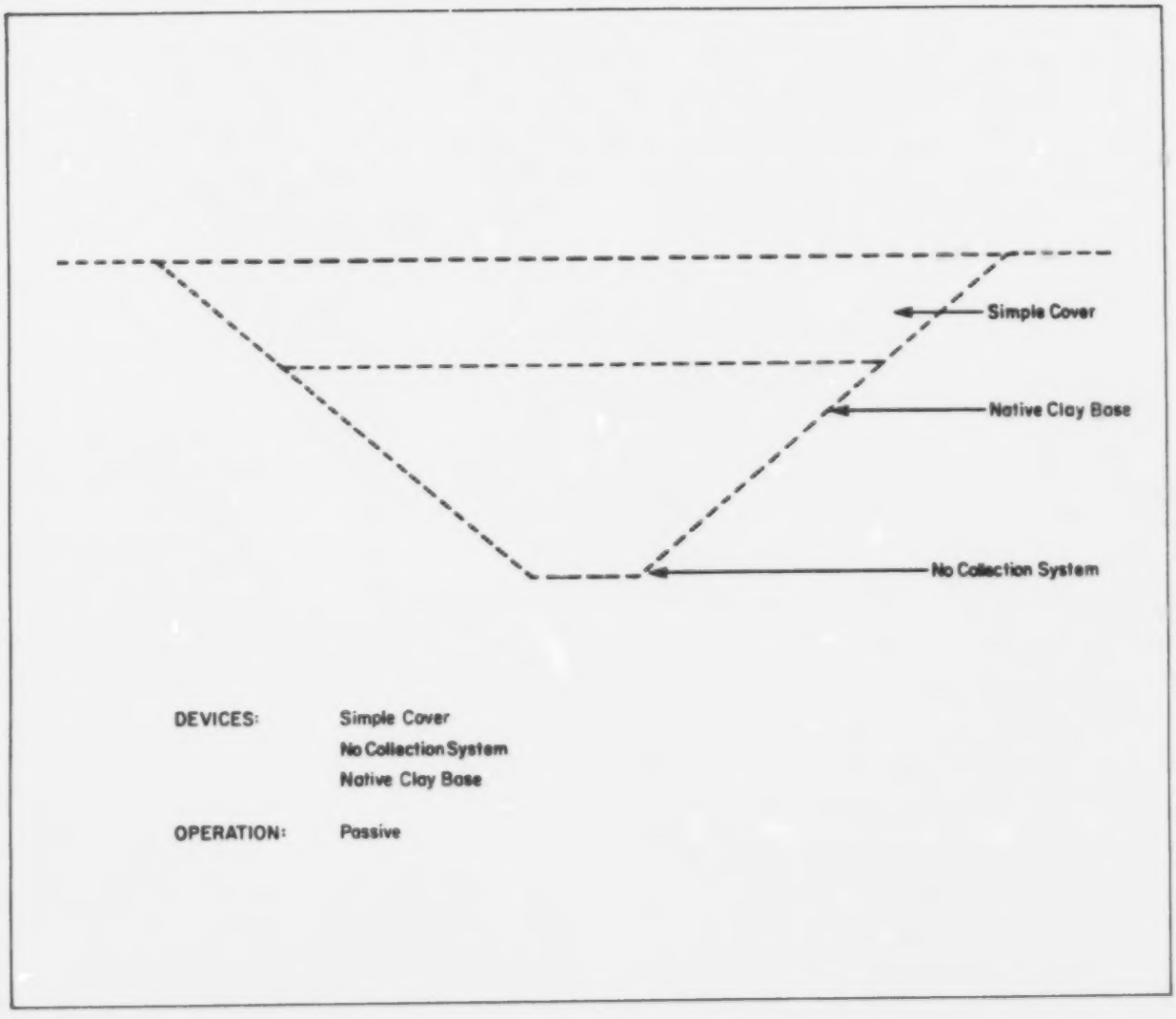
The range of alternatives represented by the chosen systems includes high and low control of contaminants, short and long-term performance, repairable and non-repairable or replaceable devices.

As noted in the fifth point, active operation of the leachate control systems was assumed. Leachate control systems could also be installed and not operated except as contingency measures should leachate quality of concern be detected. This option is considered as a sensitivity analysis.

The systems developed for evaluation were:

BASE CASE: (passive)	- simple cover - no leachate collection system - native clay base
SYSTEM 1: (active-non-repairable)	- complex cover - underdrain layer - complex liner
SYSTEM 2: (active-non-repairable)	- simple cover - underdrain layer - native clay base
SYSTEM 3: (active-repairable or replaceable)	- simple cover - perimeter drain - native clay base

Figures 9 to 11 are schematic representations of the three systems. These systems were evaluated against the Base Case option (Figure 8) used in comparison of landfill concepts which assumed the native environment with only a simple cover added. This option represents the long-term performance of the shallow entombed concept regardless of the system of devices chosen.



Not to Scale

Figure 8
BASE CASE

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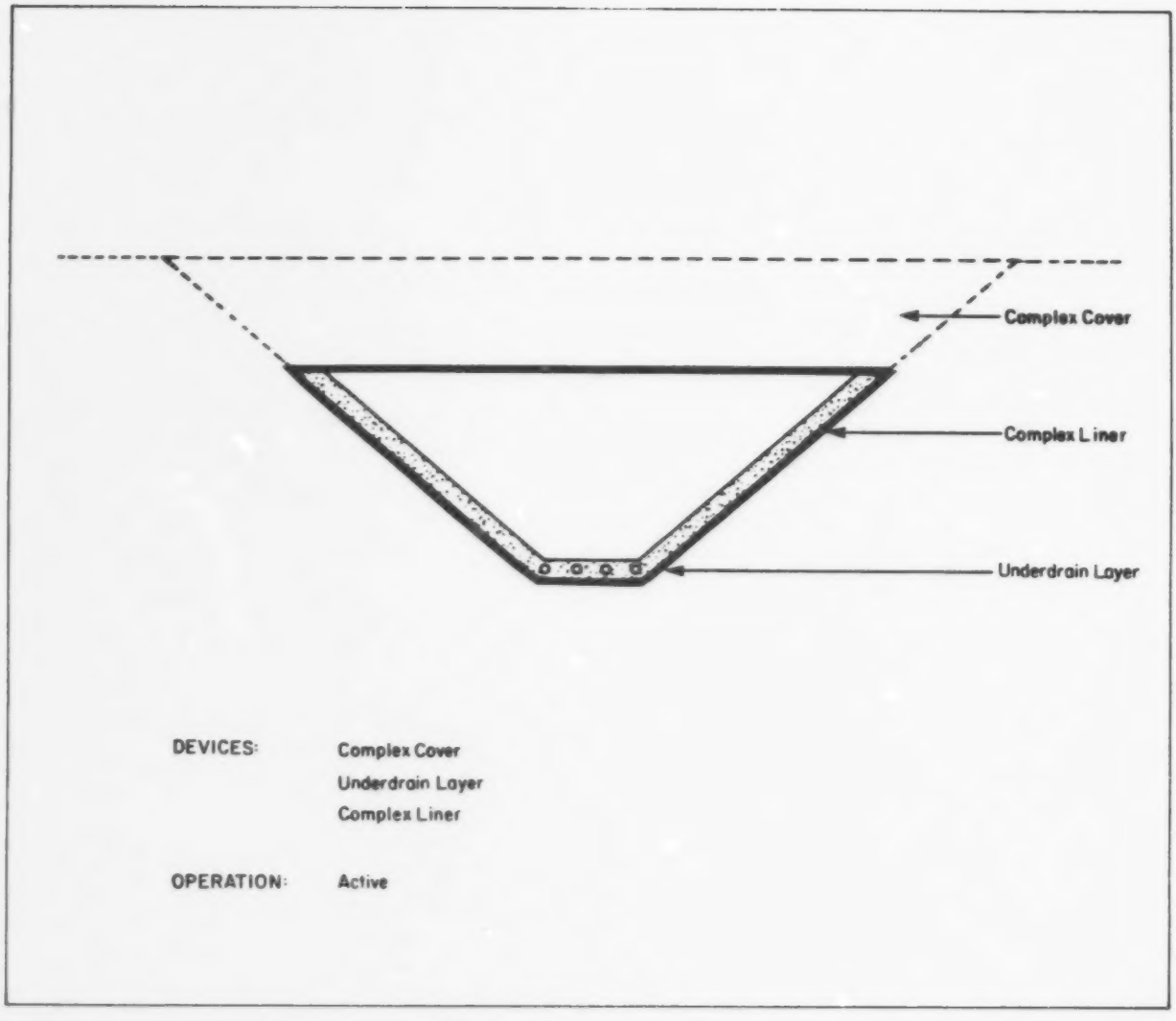

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Figure 9

SYSTEM I

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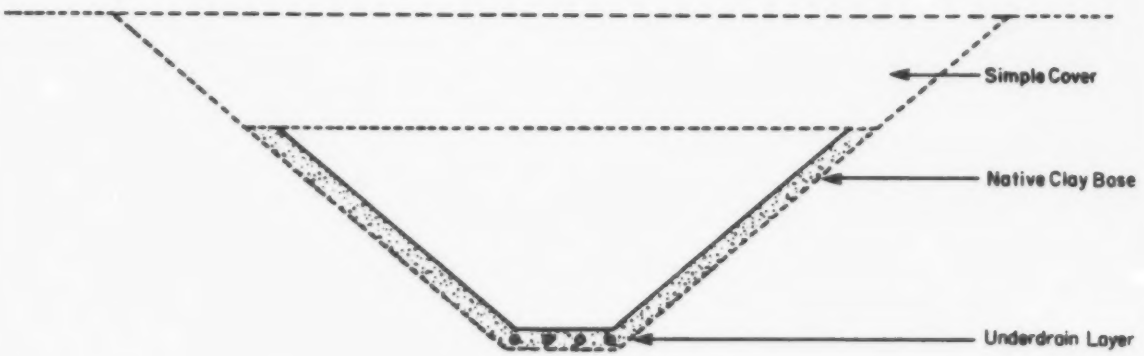

DEVICES: Simple Cover
Underdrain Layer
Native Clay Base

OPERATION: Active

Not to Scale

Figure 10
SYSTEM 2

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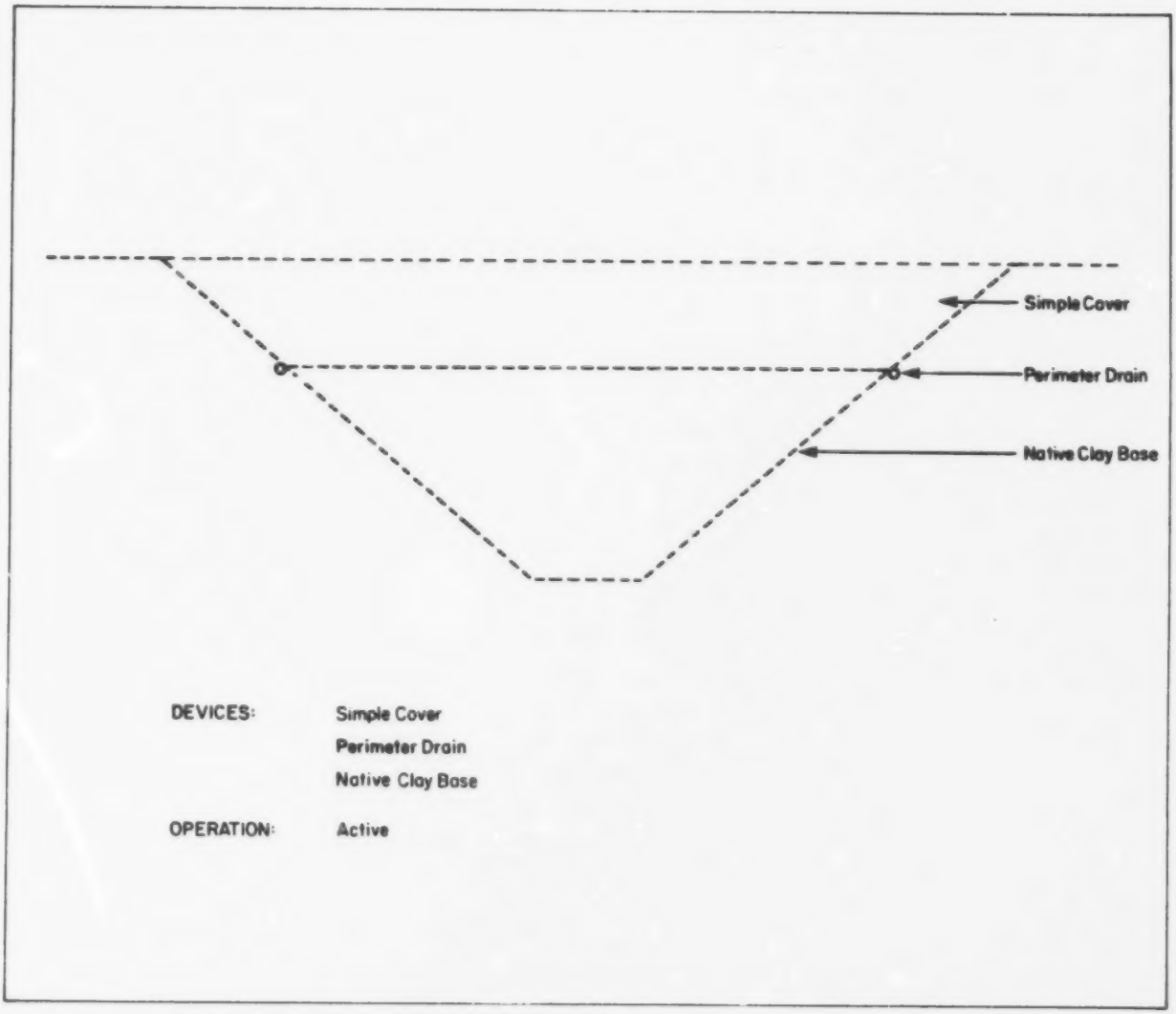

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Figure 11
SYSTEM 3

Systems 1 and 2 represent non-repairable devices (therefore of short-term function only). System 1 represents a complete system of devices to determine impacts based on active engineering controls in the short-term. System 2 was chosen to show the difference in performance from System 1 using the leachate collection system only.

System 3 has a repairable leachate collection system which will therefore function over the short and long-term as long as replacement and maintenance are undertaken.

The failure of all the engineered devices for Systems 1, 2 and 3 will result in long-term performance equivalent to the Base Case (Ref: GLAL[4]).

3.6.4 ESTABLISHMENT OF SUB-CRITERIA FOR EVALUATION

The sub-criteria used for evaluation of the systems of devices and their mode of operation and development method are identified and described as follows:

- **PERFORMANCE**

  - Short-term Performance) Developed by GLAL and documented
  - Long-term Performance) (Ref: GLAL[4]).

- **FLEXIBILITY - OPERATIONS**

  - Relates to the use of a leachate collection device in the system and whether both active and passive modes of operation are possible.

- **RELIABILITY**

  - Regular Maintenance Requirements (during operations) - Refer to Section 3.5.4

  - Spares - Requirement) Refer to Section 3.5.4
    - Availability)

  - Proven Technology - Relates to whether the technologies used for leachate control have been used in similar types of facilities and have operated as designed for more than one year.

  - Long-term Maintenance Requirements - Refer to Section 3.5.4.

- **SAFETY**

  - Occupational risk during normal or upset conditions) Refer to Section 3.5.4
  - Environmental risk during upset conditions)

- **OPERATIONS**

  - Complexity of Process)
  - Ease of Monitoring)
  - Off-site Effects)

- **COMMERCIAL AND ECONOMIC**

  - Costs - Refer to Section 3.5.4

- Landfill Capacity - The capacity of the landfill based on volume created. Calculations are based on a "Typical" Operations Case" with regard to volume of material solidified. The typical case estimated typical operating conditions with regard to characteristics of the waste. Discharge of effluent from the site was assumed to be via evaporation. The typical case provided a consistent basis for comparing the landfill devices.

o **CANADIAN BENEFITS**

- Systems of devices were examined to determine whether any benefits would accrue to Canada, should one system be selected over another. This criterion is a measure of the potential positive impacts of the facility.

3.6.5 EVALUATION OF SYSTEMS OF DEVICES ASSUMING CELL DEVELOPMENT METHOD

Introduction

In this section, the three systems of devices and the base case were evaluated based on the criteria and sub-criteria identified in Sections 3.3 and 3.6.4. In order to ensure consistency in the evaluation process a development method assumption was required. Cell development method was assumed. The cell method was considered reasonable as a base case for site selection because it was conservative relative to land area requirements (Ref: Monenco Limited[11]). A subsequent step in the evaluation process tests the sensitivity of the development method to the preferred system (Section 3.6.6).

Comparative Evaluation of Systems of Devices

Table 5 rates each system with respect to the criteria and sub-criteria. The ratings for the sub-criteria are developed by scaling the results into one of four levels. Subjective judgements are applied to develop ratings for criteria and sub-criteria. Table D-1 in Appendix D provides the rationale for the ratings in each sub-criterion.

Selection of Preferred System of Devices

The only differences between the three systems of devices and the Base Case are with regard to performance and commercial and economic criteria. All three options have the flexibility for either active or passive modes of operation, are equally reliable and safe and have equal operations ratings.

With regard to performance, Systems 1 and 2 provide the best short-term performance. The performance of the systems is controlled by the actively operated underdrains. These underdrains produce a hydraulic gradient towards the landfill. In the case of System 2, the gradient encourages ground water from outside of the landfill area to flow towards the landfill and into the underdrains. The liner in System 1 minimizes the amount of this ground water which enters the underdrains. This results in a reduction in the quantity of water (i.e. leachate and ground water) requiring treatment for System 1. This does not affect performance but is cost related. The perimeter drain included in System 3 provides lower short-term performance with respect to Systems 1 and 2, but the best long-term performance because the perimeter drain is a repairable device. However, the perimeter drain mainly controls surface water and weathered zone pathways. These pathways are of least concern for the shallow entombed concept where the solidified material is placed beneath the weathered zone. Therefore, based on performance, Systems 1 and 2

TABLE 5

COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

CRITERIA	SUB-CRITERIA	BASE CASE	SYSTEM 1	SYSTEM 2	SYSTEM 3	REMARKS
SHORT-TERM PERFORMANCE	• RATE OF CONTAMINANT TRANSPORT TO AQUIFER	LOW	LOWEST*	LOWEST*	LOWER	
	• RATE OF CONTAMINANT TRANSPORT TO SURFACE	LOW	LOWER*	LOWER*	LOWER*	
	• RATE OF CONTAMINANT TRANSPORT IN WEATHERED ZONE	LOW	LOWER*	LOWER*	LOWER*	
LONG-TERM PERFORMANCE (NON-REPAIRABLE DEVICES FAILURE)	• RATE OF CONTAMINANT TRANSPORT TO AQUIFER	LOW	LOW	LOW	LOWER*	
	• RATE OF CONTAMINANT TRANSPORT TO SURFACE	LOW	LOW	LOW	LOWER*	
	• RATE OF CONTAMINANT TRANSPORT IN WEATHERED ZONE	LOW	LOW	LOW	LOWER*	
FLEXIBILITY	• OPERATIONS	LOW	INTERMEDIATE*	INTERMEDIATE*	INTERMEDIATE*	- Systems 1, 2 and 3 can be operated in a passive mode
RELIABILITY	• REGULAR MAINTENANCE REQUIREMENTS (DURING OPERATIONS)	LOW*	INTERMEDIATE	INTERMEDIATE	INTERMEDIATE	
	• SPARES - REQUIREMENT	LOW*	INTERMEDIATE	INTERMEDIATE	INTERMEDIATE	
	- AVAILABILITY	N/A*	HIGH	HIGH	HIGH	Req'd materials for Systems 1, 2 and 3 should be readily available

* Indicates best rating for sub-criterion.

Note: Evaluation based on Cell Development Method.

TABLE 5

COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

(Continued)

CRITERIA	SUB-CRITERIA	BASE CASE	SYSTEM 1	SYSTEM 2	SYSTEM 3	REMARKS
RELIABILITY (Cont'd)	• PROVEN TECHNOLOGY	YES	YES	YES	YES	- All devices for systems have finite life expectancy
	• LONG-TERM MAINTENANCE REQUIREMENTS	LOW*	INTERMEDIATE	INTERMEDIATE	INTERMEDIATE	
SAFETY	• OCCUPATIONAL RISK DURING NORMAL OR UPSET CONDITIONS AND ENVIRONMENTAL RISKS ON UPSET CONDITIONS	LOW	LOW	LOW	LOW	
OPERATIONS	• COMPLEXITY OF PROCESS	LOW*	INTERMEDIATE	INTERMEDIATE	INTERMEDIATE	
	• EASE OF MONITORING - PERFORMANCE	INTERMEDIATE	INTERMEDIATE	INTERMEDIATE	INTERMEDIATE	
	- ENVIRONMENTAL	INTERMEDIATE	INTERMEDIATE	INTERMEDIATE	INTERMEDIATE	
	• OFF-SITE EFFECTS - NOISE - DUST - MATERIAL IMPORT	LOW	INTERMEDIATE	INTERMEDIATE	INTERMEDIATE	
COMMERCIAL AND ECONOMIC	• ACTIVE FACILITY COSTS	LOWEST*	HIGH	INTERMEDIATE	LOW	
	• POST-ACTIVE FACILITY COST	LOW*	INTERMEDIATE	INTERMEDIATE	HIGH	
	• LANDFILL CAPACITY	LOW	LOW	LOW	LOW	- Development method has significant effect on landfill life
CANADIAN BENEFIT						- Not applicable

* Indicates best rating for sub-criterion.

Note: Evaluation based on cell development method.

are preferred. This is supported by the fact that the perimeter drain of System 3 can be installed for any system of devices at any time (i.e. as a contingency measure). All of the systems improve performance over the Base Case.

The differences with regard to the commercial and economic criterion are considered to be less important than those for performance. Hydrogeologic performance is related to the most important goals of OWMC - minimizing risk to human health and minimizing environmental impact. However, the cost differences identified between the systems are not significant in comparison to the overall Facility cost. Table 6 shows that System 3 with a native clay base, simple cover and perimeter drain, has the lowest active Facility costs next to the Base Case. System 2 has intermediate costs. The addition of more complex cover and liner makes the costs for System 1 the greatest. Post-active Facility costs are higher for System 3 because of the long-term maintenance and repair required for the perimeter drain. The systems have similar capacities (see Table 7).

Given that performance is considered more significant than costs (based on the priority of OWMC goals), the choice is limited to Systems 1 and 2. These systems have better short-term performance for the aquifer pathway which is of greatest benefit for the shallow entombed landfill concept. Systems 1 and 2 have equal performance except that System 2 has greater flexibility. For System 2 there is the option of not operating the underdrain so that reliance is on the natural environment. System 1 includes a complex liner so that complete reliance on the natural environment is not an option until the liner fails.

System 2 has lower active Facility costs than System 1.

TABLE 6

ACTIVE FACILITY COSTS

COST (Total Annual Costs - All Future Costs Discounted)
($1000's)

	BASE CASE	SYSTEM 1	SYSTEM 2	SYSTEM 3
CELL	13362	26231	15092	14444

TABLE 7

LANDFILL LIFE ESTIMATES

FOR CELL DEVELOPMENT METHOD[1]

SYSTEM	CELL
BASE CASE	13
SYSTEM 1	11.5
SYSTEM 2	12.5
SYSTEM 3	13

---

1 - Based on 3:1 in-ground side slopes.
- Based on the "Typical Operations Case" rate of solidified production. Note that solidification assumption used can increase or decrease landfill lives for all systems but minor differences in landfill lives will remain.
- Based on a peak rate of incoming waste of 300 000 t/a in year 10.

Overall, System 2 is preferred because it provides comparable performance to System 1, greater flexibility of operations and lower cost.

Sensitivity to Mode of Operation

In the evaluation of engineered devices, the mode of operation for the leachate collection systems was assumed to be active for Systems 1, 2 and 3. An alternative is to install the leachate collection systems but operate them only in the event that monitoring finds leachate with a quality of concern.

The long-term performance of all three systems will be equal (because devices will fail) with leachate movement controlled by the natural hydrogeologic setting. An exception would be System 3, if there is long-term repair and maintenance of the perimeter drain. With continued operation, this device would marginally improve long-term performance of the shallow entombed concept for the surface water and weathered zone pathways, which are of less concern since the solidified material is placed below the weathered zone. Therefore, the changes in short-term performance are the focus of the evaluation for mode of operation. A change from active to passive mode will not affect the preference for System 2 with regard to short-term performance and cost evaluations.

The advantages of active operation is that it will improve short-term performance for both Systems 1 and 2.

The mode of operations will therefore be passive unless analysis of leachate quality, environmental impacts and hydrogeologic performance of the landfill warrants active operation.

3.6.6 EVALUATION OF DEVELOPMENT METHODS FOR THE PREFERRED SYSTEM OF DEVICES

Introduction

In this section, the three development methods are evaluated for the preferred system of devices based on the criteria and sub-criteria identified in Sections 3.3 and 3.6.4. The three methods were described in Section 3.4.3 and are shown in Figures 12 to 14, Pages 72 to 74.

Comparative Evaluation of Development Methods

Table 8 rates the preferred system for each development method with respect to the evaluation criteria and sub-criteria. The same format as in the previous evaluation (Section 3.6.5) is used. Table D-2 in Appendix D provides the rationale for the ratings in each sub-criterion.

Table 8 shows that the only differentiation between the development methods is under the commercial and economic criterion. The first sub-criterion is landfill capacity. Table 9 shows that both cell and trench have similar landfill lives. Area development provides approximately double the landfill life of either of the other development methods (refer to Table 9). Therefore area development is rated high. This capacity difference is also illustrated on Figure 15 which is a cross-section of the area method with cell or trench development superimposed.

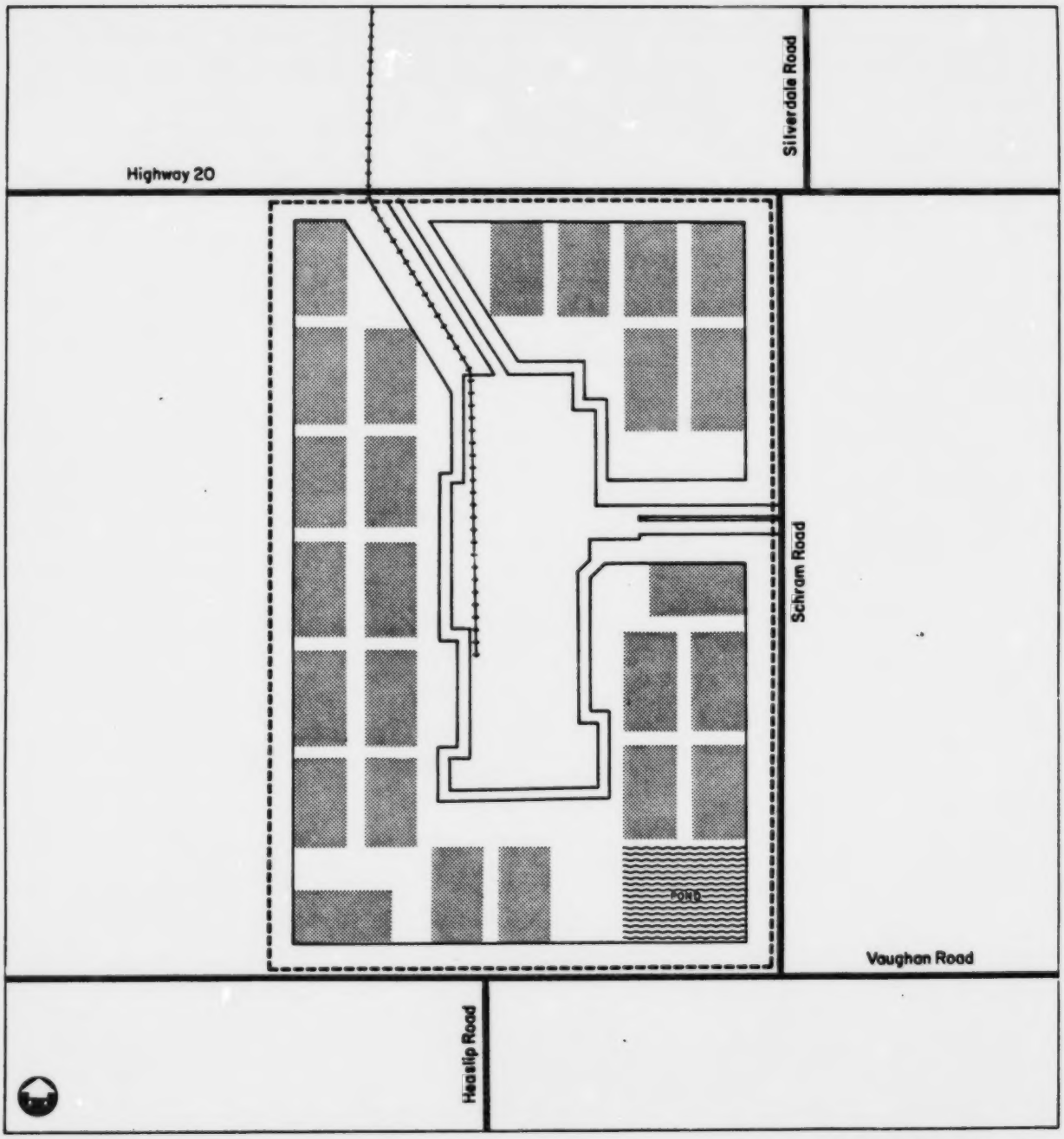

Figure 12

LF-9 CENTRAL • SHALLOW ENTOMBED • CELL DEVELOPMENT

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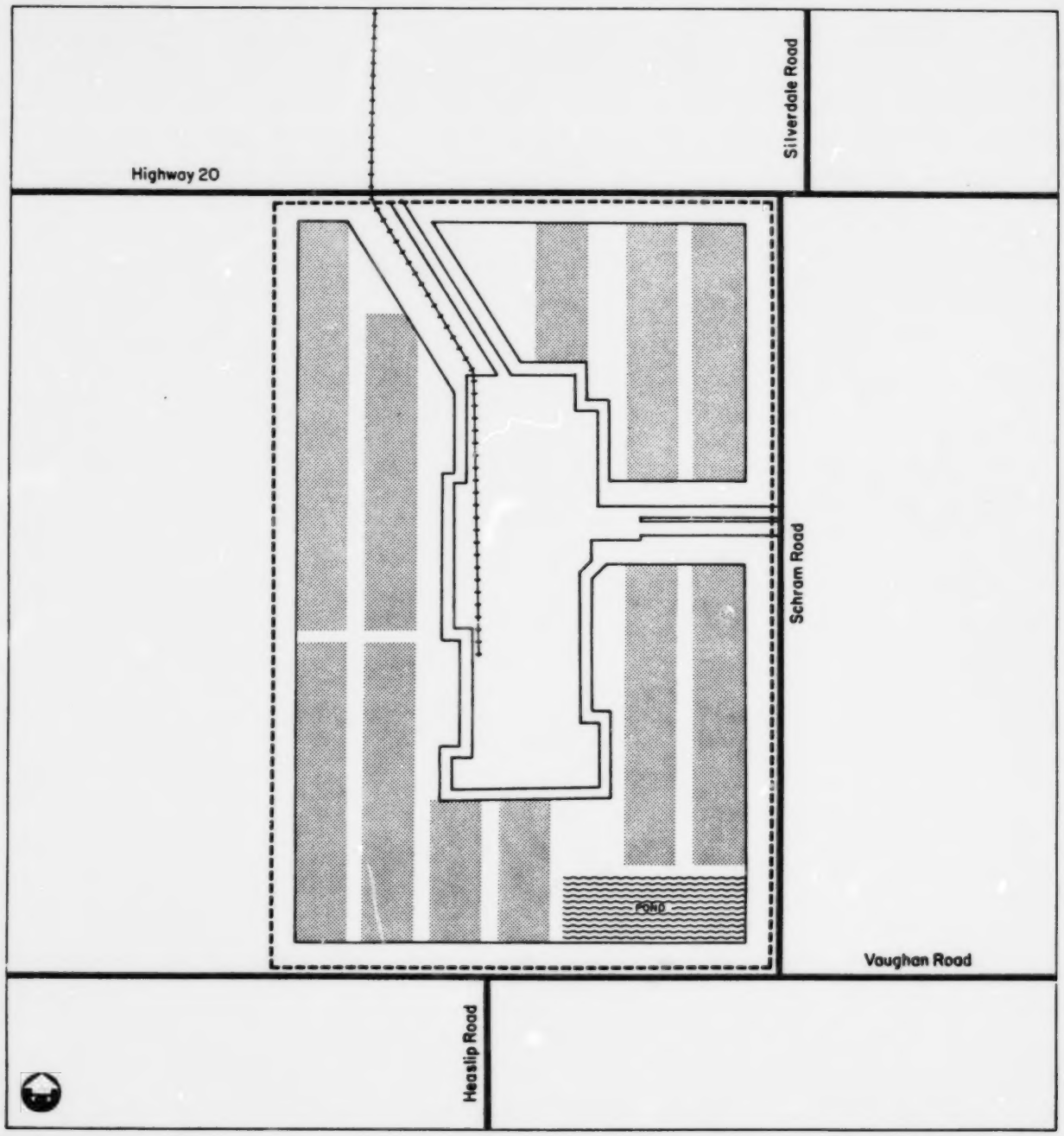

Figure 13

LF-9 CENTRAL • SHALLOW ENTOMBED • TRENCH DEVELOPMENT

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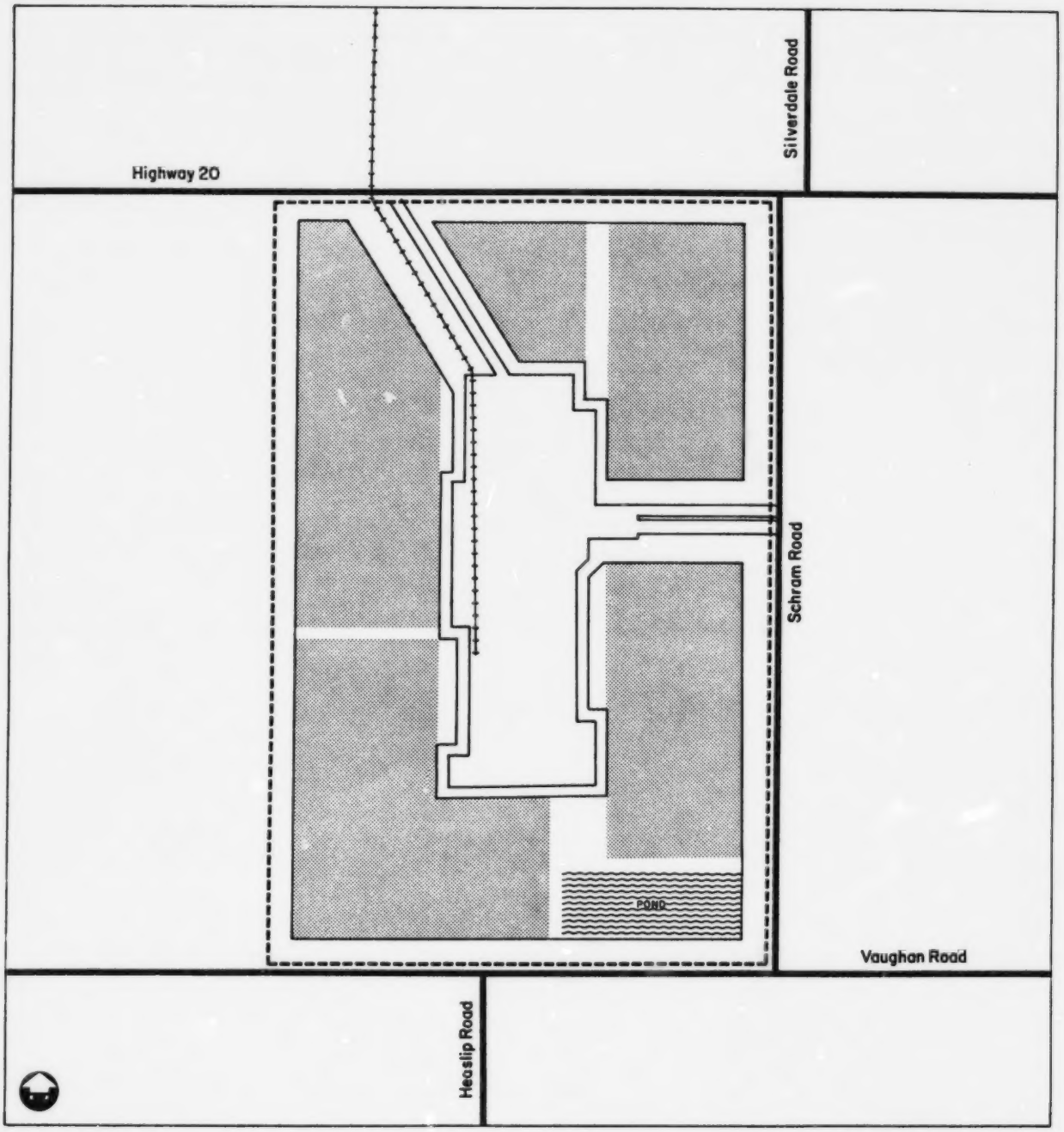

Figure 14

LF-9 CENTRAL • SHALLOW ENTOMBED • AREA DEVELOPMENT

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TABLE 8

COMPARATIVE EVALUATION OF DEVELOPMENT METHOD OPTIONS

CRITERIA	SUB-CRITERIA	CELL	TRENCH	AREA	REMARKS
SHORT-TERM PERFORMANCE	• RATE OF CONTAMINANT TRANSPORT TO AQUIFER	LOW	LOW	LOW	
	• RATE OF CONTAMINANT TRANSPORT IN SURFACE	LOW	LOW	LOW	
	• RATE OF CONTAMINANT TRANSPORT IN WEATHERED ZONE	LOW	LOW	LOW	
LONG-TERM PERFORMANCE (NON-REPAIRABLE DEVICES FAILURE)	• RATE OF CONTAMINANT TRANSPORT TO AQUIFER	LOW	LOW	LOW	
	• RATE OF CONTAMINANT TRANSPORT TO SURFACE	LOW	LOW	LOW	
	• RATE OF CONTAMINANT TRANSPORT IN WEATHERED ZONE	LOW	LOW	LOW	
FLEXIBILITY	• OPERATIONS	LOW	LOW	LOW	
RELIABILITY	• REGULAR MAINTENANCE REQUIREMENTS (DURING OPERATIONS)	LOW	LOW	LOW	
	• SPARES - REQUIREMENT	LOW	LOW	LOW	
	- AVAILABILITY	N/A	N/A	N/A	

* Indicates best rating for sub-criterion.

Note: Sensitivity Analysis based on System 1.

TABLE 8

COMPARATIVE EVALUATION OF DEVELOPMENT METHOD OPTIONS (CONTINUED)

CRITERIA	SUB-CRITERIA	CELL	TRENCH	AREA	REMARKS
RELIABILITY (Cont'd)	• PROVEN TECHNOLOGY	YES	YES	YES	
	• LONG-TERM MAINTENANCE REQUIREMENTS	LOW	LOW	LOW	
SAFETY	• OCCUPATIONAL RISK DURING NORMAL OR UPSET CONDITIONS AND ENVIRONMENTAL RISKS ON UPSET CONDITIONS	LOW	LOW	LOW	
OPERATIONS	• COMPLEXITY OF PROCESS	LOW	LOW	LOW	
	• EASE OF MONITORING - PERFORMANCE	INTERMEDIATE	INTERMEDIATE	INTERMEDIATE	
	• OFF-SITE EFFECTS - TRANSPORT OF MATERIALS	INTERMEDIATE	INTERMEDIATE	INTERMEDIATE	
COMMERCIAL AND ECONOMIC	• ACTIVE FACILITY COSTS	HIGH	INTERMEDIATE	LOW*	
	• POST-ACTIVE FACILITY COST	LOW	LOW	LOW	
	• LANDFILL CAPACITY	LOW	LOW	HIGH	
CANADIAN BENEFIT		-	-	-	

* Indicates best rating for sub-criterion.

Note: Sensitivity Analysis based on System 1.

TABLE 9

LANDFILL LIFE ESTIMATES FOR DEVELOPMENT METHOD OPTIONS[1]

DEVELOPMENT METHOD (Years)

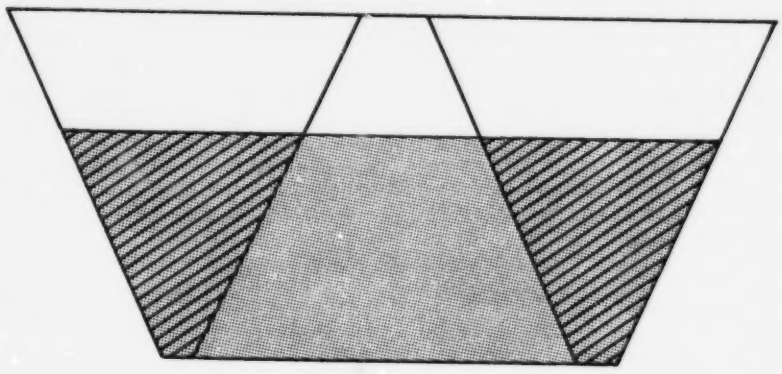
SYSTEM	CELL	TRENCH	AREA
BASE CASE	13	15	29.5
SYSTEM 1	11.5	13	27
SYSTEM 2	12.5	14	28.5
SYSTEM 3	13	15	29.5

---

1. Based on 3:1 in-ground side slopes.

   Based on the "Typical Operations Case" rate of solidified material production.

   Based on a peak rate of incoming waste of 300 000 t/a in year 10.



Cross-Section through Landfill for Area vs. Cell or Trench Development

Legend:

Solidified Mass for Cell / Trench Development Method

Additional Solidified Mass for Area Development Method

Not to Scale

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Figure 15
CAPACITY DIFFERENCES FOR DEVELOPMENT METHODS

The next sub-criterion is active Facility cost (i.e. those costs associated with the period when the landfill is being filled). Table 10 provides the cost of each development method on a unit volume basis. Using this basis, area method has the lowest cost with trench second and cell third.

An issue that was not considered in this evaluation is contaminant loading. For a given volume of solidified mass the contaminant loading is constant. Previously, it was demonstrated that the area development method utilizes landfill area more efficiently. Therefore, for a fixed landfill size, the area development method provides for a greater volume capacity than trench or cell methods. As a result, the area development method increases the contaminant loading on a fixed landfill area over the other development methods. The rate of contaminant release from the solidified mass and concentration of the contaminants in the leachate is the subject of further investigation. When this work is completed, the decision regarding the acceptability of the area development method will be confirmed.

Pending this confirmation, the area method of development has been used as a basis for landfill design.

3.7 SUMMARY OF LANDFILL CONCEPT AND FEATURES EVALUATION AND SELECTION

Shallow entombed is the proposed landfill concept. It provides the best long-term performance without reliance on engineered devices. Migration of leachate to the surface water and weathered zone pathways is minimized for this option because the solidified material is placed below the weathered zone. This concept provides flexibility for active or passive operation and for

TABLE 10
SUMMARY OF UNIT COSTS FOR DEVELOPMENT AND OPERATIONS[1]
($/cu.m)

	BASE CASE	SYSTEM 1	SYSTEM 2	SYSTEM 3
CELL	9.00	20.78	10.81	9.73
TRENCH	8.10	18.60	9.67	8.71
AREA	4.68	9.58	5.39	4.81

1. Unit costs based on net present value divided by total site capacity
   - Future costs discounted at 4%.
   - Costs based on "Typical Operations Case".

various systems of devices to improve short-term performance particularly with regard to the aquifer pathway. The high ratings for the performance and flexibility of the criteria of the shallow entombed concept relate directly to OWMC's goals of minimizing risk to human health and minimizing environmental impact.

The proposed system of devices for the shallow entombed concept is a native clay base, simple cover and underdrain. This system provides high short-term performance if actively operated with the flexibility to be operated actively or left in the passive mode. In the passive mode, the system will not impact upon or interfere with the natural environmental processes in any way, thereby allowing for monitoring of conditions representing long-term functioning (after devices fail). The active mode will provide a high level of control should leachate quality ever be of concern. The qualities of the proposed system of devices are all related to the OWMC goals to minimize risk to human health and to minimize environmental impact.

The proposed method of development for the shallow entombed landfill concept and system of devices is the area method pending impact assessment of the contaminant loading issue. The only differences among the methods relate to the commercial and economic criterion. The cost for this method is the lowest and it has a substantially longer landfill life.

The leachate collection system for the proposed concept can be operated actively or left in the passive mode. The advantages and disadvantages to these options will be considered further when additional information regarding waste characteristics, environmental impact and performance are available.

CHAPTER 4
CONCEPTUAL DESIGN

4.1 INTRODUCTION

The previous chapters of this report have developed the basis for conceptual design of the engineered landfill, through a detailed assessment and evaluation of available landfill concepts and features. The assessment included not only technical criteria, but also criteria based on OWMC's philosophy and goals (Section 2.2). Using the landfill concept and features recommended by the Landfill Working Group (see Page 5) and approved by OWMC as a basis, this chapter presents the conceptual design of the proposed engineered landfill. The results of the previous evaluations which form the basis for this conceptual design are listed below:

- shallow entombed landfill concept;
- area method of development;
- a system of devices including a simple cover, native clay base and an underdrain for leachate collection.

Conceptual design within this chapter begins with an overview of the entire landfill system with reference to the Engineered Landfill Block Flow Diagram, (Figure 18, Page 96).

The design of the individual elements of the landfill are described including dimensions, quantities and functions. In cases where several alternatives are available for a particular component, an evaluation is carried out to determine the preferred alternative (referred to as optimization). The individual elements are then integrated within a description of landfill development and operations both initially and on an ongoing basis.

4.2 PREMISES AND POSTULATES FOR CONCEPTUAL LANDFILL DESIGN

4.2.1 INTRODUCTION

Premises and postulates for the design of the engineered landfill have been stated in Sections 2.6 and 2.7 respectively. As previously defined, premises refer to information provided by OWMC or by other studies undertaken for OWMC which have been taken as departures for new work. Postulates are defined as assumptions or hypotheses which are basic to the conceptual design.

The premises and postulates defined in Sections 2.6 and 2.7 were general in nature and were sufficient for the purpose of evaluating the landfill concept and features. There are a number of more specific premises and postulates which were identified for the purposes of conceptual design. These are presented in the following sections under the headings:

- Volumes of Solidified Material
- Geotechnical/Hydrogeologic Criteria
- Facility Layout
- Leachate Quantities

4.2.2 VOLUMES OF SOLIDIFIED MATERIAL

The following provides the premises and postulates concerning the volumes of solidified material for landfilling.

Premises

- Volumes of solidified material for landfilling were provided by Monenco Limited. Three mass balance scenarios of incoming waste were developed (for further detail refer to Monenco[6]). These scenarios are:

  - "Typical Operations Case"
  - "High Effluent Case"
  - "High Solidified Waste Case"

- The annual volumes of solidified material for each scenario of incoming waste are contained in Tables 11 and 12. Table 11 is based on a constant volume of incoming waste of 150 000 tonnes/annum (t/a) after year 5. Table 12 is based on a constant volume of incoming waste of 300 000 t/a after year 10.

- The proportion of low solids to high solids solidified material is dependent on which incoming waste scenario is considered. There are four streams of solidified material for landfilling:

  - low solids solidified material from the solidification plant;

  - high solids solidified material from the solidification plant;

  - high solids solidified material from incineration; and

  - slag from incineration.

TABLE 11

VOLUMES OF SOLIDIFIED MATERIAL FOR LANDFILLING*

(BASED ON A MAXIMUM WASTE INFLOW RATE OF 150 000 TONNES/ANNUM)

Year of Operation	Incoming Waste	SOLIDIFIED MATERIAL TO LANDFILL (m^3)			
		"High Effluent Case"	"Typical Operations Case"		"High Solidified Waste Case"
		Annual	Annual	Cumulative	Annual
	(t)	(m^3)	(m^3)	(m^3)	(m^3)
1	50,000	14,300	**28,800**	**28,800**	48,200
2	70,000	20,000	**40,400**	**69,200**	67,500
3	105,000	29,900	**60,600**	**129,800**	101,200
4	130,000	37,100	**75,000**	**204,800**	125,400
5	150,000	42,800	**87,200**	**292,000**	144,600
6	150,000	42,800	**87,200**	**379,200**	144,600
7	150,000	42,800	**87,200**	**466,400**	144,600
8	150,000	42,800	**87,200**	**553,600**	144,600
9	150,000	42,800	**87,200**	**640,800**	144,600
10	150,000	42,800	**87,200**	**728,000**	144,600
11	150,000	42,800	**87,200**	**815,200**	144,600
12	150,000	42,800	**87,200**	**902,400**	144,600
13	150,000	42,800	**87,200**	**989,600**	144,600
14	150,000	42,800	**87,200**	**1,076,800**	144,600
15	150,000	42,800	**87,200**	**1,164,000**	144,600
16	150,000	42,800	**87,200**	**1,251,200**	144,600
17	150,000	42,800	**87,200**	**1,338,400**	144,600
18	150,000	42,800	**87,200**	**1,425,600**	144,600
19	150,000	42,800	**87,200**	**1,512,800**	144,600
20	150,000	42,800	**87,200**	**1,600,000**	144,600

* Based on values provided by Monenco Ltd. (Ref: Monenco[6]).

Bold Print indicates values used for design.

TABLE 12

VOLUMES OF SOLIDIFIED MATERIAL FOR LANDFILLING* (BASED ON A MAXIMUM WASTE INFLOW RATE OF 300 000 TONNES/ANNUM)

Year of Operation	Incoming Waste	SOLIDIFIED MATERIAL TO LANDFILL (m^3)			
		"High Effluent Case"	"Typical Operations Case"		"High Solidified Waste Case"
		Annual	Annual	Cumulative	Annual
	(t)	(m^3)	(m^3)	(m^3)	(m^3)
1	50,000	14,300	28,800	28,800	48,200
2	70,000	20,000	40,400	69,200	67,500
3	105,000	29,900	60,600	129,800	101,200
4	130,000	37,100	75,000	204,800	125,400
5	150,000	42,800	87,200	292,000	144,600
6	180,000	51,400	103,800	395,800	173,600
7	210,000	59,900	121,200	517,000	202,400
8	240,000	68,500	130,500	655,500	232,000
9	270,000	77,000	155,700	811,200	260,300
10	300,000	85,000	172,300	983,500	289,300
11	300,000	85,000	172,300	1,155,800	289,300
12	300,000	85,000	172,300	1,328,100	289,300
13	300,000	85,000	172,300	1,500,400	289,300
14	300,000	85,000	172,300	1,672,700	289,300
15	300,000	85,000	172,300	1,845,000	289,300
16	300,000	85,000	172,300	2,017,300	289,300
17	300,000	85,000	172,300	2,189,600	289,300
18	300,000	85,000	172,300	2,361,900	289,300
19	300,000	85,000	172,300	2,534,200	289,300
20	300,000	85,000	172,300	2,706,500	289,300

* Based on values provided by Monenco Ltd. (Ref: Monenco[6]).

A summary of the solidified materials streams for 150 000 t/a and 300 000 t/a is given in Table 13.

- OWMC intends to operate the landfill only during daylight hours between 7:00 a.m. and 7:00 p.m. An interim storage building near the load-out facility will receive and store material produced in the other two shifts (afternoon and night shifts). The stored material will be transferred to the landfill during daylight hours by truck. (Ref: Appendix E).

Postulates

- Landfill design is based on the "Typical Operations Case" of solidified material production. Volumes from the other two scenarios, "High Effluent Case" and "High Solidified Waste Case", are evaluated as a sensitivity analysis of the landfill (i.e. variance in site lives for the other scenarios).

- The high solids solidified material is to be trucked to the landfill from a load-out facility located at the north end of the Central Operating Area (COA). (Ref: Appendix E).

- The low solids solidified material will be pumped to the landfill via pipeline. (Ref: Appendix E).

- The landfill will operate 250 days/annum (50 weeks/annum, 5 days/week).

- For design purposes the volumes of solidified material transported to the landfill are considered to be the same each day. This is based on the fact that the solidification plant also operates five days per week. (Ref: Monenco Limited[8]).

TABLE 14

FEED STREAMS OF SOLIDIFIED MATERIAL FOR LANDFILLING

HIGH WASTE SCENARIO	150 000 T/A CAPACITY				300 000 T/A CAPACITY			
	High Solids From Solidification Plant	Low Solids From Solidification Plant	Slag From Incineration	Solidified Material From Incineration	High Solids From Solidification Plant	Low Solids From Solidification Plant	Slag From Incineration	Solidified Material From Incineration
1. "High Effluent Case"	25 700	17 300	2 700	12 000	51 400	34 500	5 400	24 000
2. "Typical Operations Case"	**72 600**	**26 000**	**2 700**	**12 000**	145 200	49 400	5 400	24 000
3. "High Solidified Waste Case"	72 600	90 800	2 700	12 000	145 200	181 500	5 400	24 000

Base Case for design is highlighted in bold print.

4.2.3 GEOTECHNICAL/HYDROGEOLOGIC CRITERIA

The following presents the premises and postulates concerning geotechnical/hydrogeologic constraints based on preliminary site investigations by Gartner Lee Associates Limited. (Ref: GLAL[5]).

Premises

- Features of the excavation side slopes are summarized below:

  - 15 m vertically deep cut.
  - 3:1 (Horizontal:Vertical (H:V)) side slopes for lower 10 m.
  - 4:1 (H:V) side slopes for upper 5 m.
  - A 10 m wide bench situated 5 m below existing ground surface.

Figure 16 provides a cross-section of the excavation as determined by GLAL (Ref: GLAL[5]). This is one of several possible side slope alternatives that was used as the basis for evaluation. Other alternatives are under consideration.

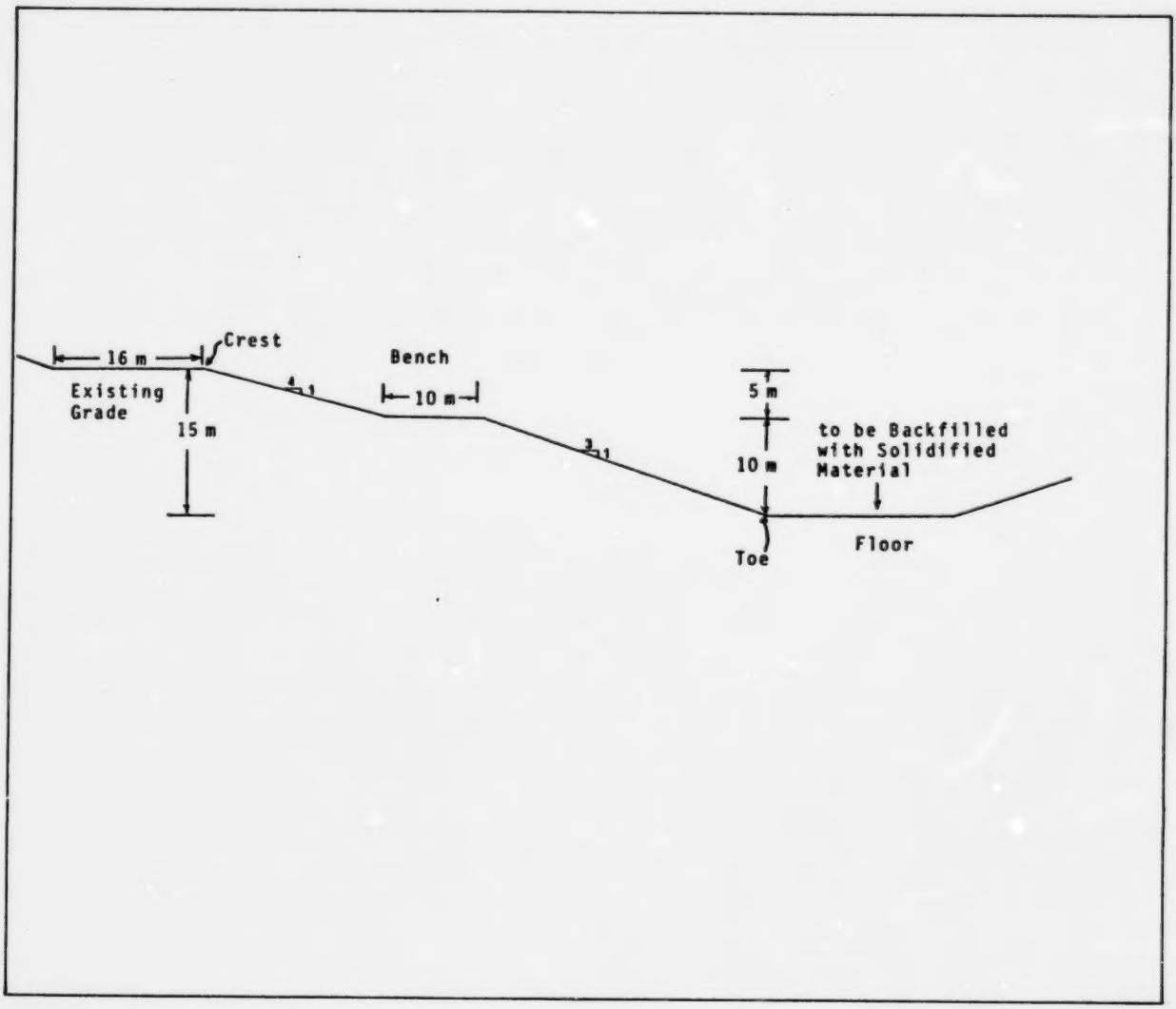
- The following premises regarding trafficability and workability were provided by GLAL (Ref: GLAL[5]).

  - Wide tracked and/or low tire pressure equipment should be used for excavation and placement of materials, i.e. bulldozers, scrapers and draglines.

  - Limit excavation of material to the drier months.

  - Limit the handling of material due to its sensitivity.

  - Divert surface runoff from working areas.



Not to Scale

DILLON
Consulting Engineers · Planners
Environmental Scientists

Figure 16
SCHEMATIC PROFILE OF EXCAVATION
Source: Gartner Lee Associates Limited, 1986

- The following premises regarding ditches were provided by GLAL (Ref: GLAL[5]).

  - The proposed diversion ditches can be excavated to any reasonable depth from a geotechnical standpoint.

  - Provided that the ditches are no deeper than 1.5 m, it is recommended that the side slope of the ditches be constructed in the order of 3:1 (H:V) to no steeper than 2:1 (H:V), depending on site conditions.

- The following premises regarding dewatering were provided by GLAL (Ref: GLAL[5]).

  - Ground water seepage into the excavation will be minimal therefore dewatering by sump-pump will be used.

- The following premises regarding construction/operational concerns were provided by GLAL (Ref: GLAL[5]).

  - A large excavation area should not be left open for more than six months at a time.

  - Excavation should be carried out in the drier (summer) months.

  - The maximum width at the base of the excavation should only be wide enough to handle the quantities of solidified material to be placed over the time-frame when excavation cannot be carried out.

  - It is anticipated that some local shallow failures and/or slumping of the slopes may take place.

4.2.4 FACILITY LAYOUT

The following section provides both the premises and postulates for the Facility layout:

Premises

- The proposed site is a fully integrated site with the landfill, physical/chemical and solidification plants and the incineration facilities all located on the same site.

- A plan of the site layout is shown in Figure 17. This plan defines the size and location of the Central Operating Area (COA), the property boundaries and plant accesses.

- The following road and corridor dimensions have been provided (Ref: Monenco Limited[6]).

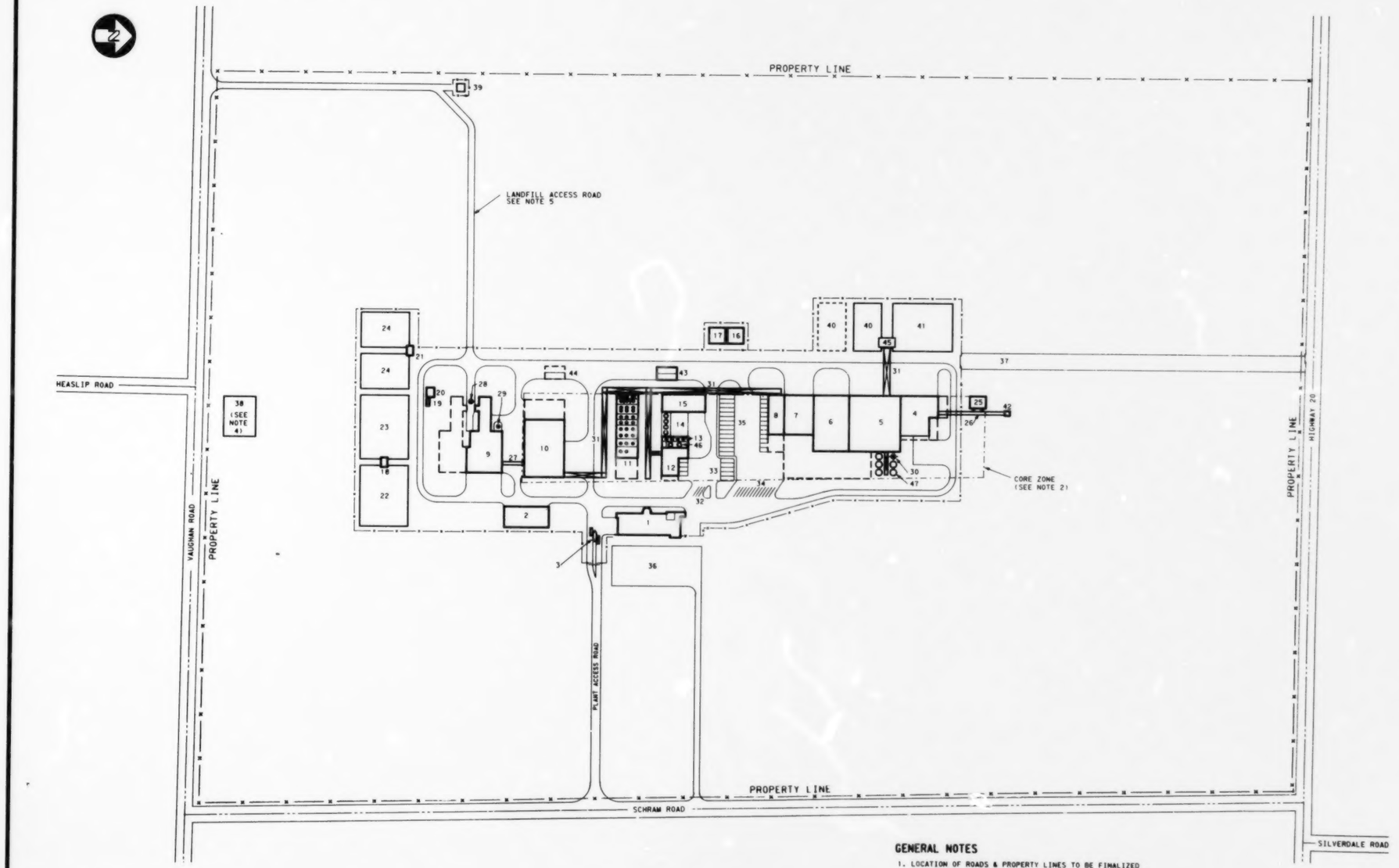
  - The main access road from the east has a width of 20 metres, including roadside ditches.

  - The road, hydro and gas corridor entering the site from the north has a total width of 20 metres, including roadside ditches.

  - The water discharge and supply corridor entering the site from the south has a total width of 6 metres.

- The access road to the car park area is relocatable and is not considered a constraint to landfilling.

- The access road entering the site from the southwest corner is relocatable and is not considered a constraint to landfilling.



LEGEND

1. ADMINISTRATION BUILDING
2. MAINTENANCE BUILDING
3. GATEHOUSE & WEIGH SCALES
4. SOLIDIFICATION PLANT
5. PHYSICAL/CHEMICAL TREATMENT PLANT
6. PHYSICAL/CHEMICAL STORAGE TANK AREA
7. INORGANIC DRUM STORAGE & HANDLING BUILDING
8. INORGANIC TANK TRUCK UNLOADING AREA
9. INCINERATION PLANT
10. ORGANIC DRUM STORAGE & HANDLING BUILDING
11. INCINERATOR TANK FARM
12. ORGANIC TANK TRUCK UNLOADING AREA
13. INCINERATOR WASTE RECEIVING TANKS
14. SEGREGATED ORGANIC STORAGE TANK AREA
15. STORAGE BUILDING
16. MAIN SUBSTATION
17. EMERGENCY POWER STATION
18. SURFACE WATER PUMPHOUSE
19. SANITARY SEWAGE PLANT
20. RAW WATER TREATMENT PLANT
21. FIREWATER PUMPHOUSE
22. SURFACE WATER POND (POTENTIALLY CONTAMINATED
23. SURFACE WATER POND (UNCONTAMINATED)
24. FIREWATER POND
25. SOLIDIFIED MATERIAL INTERIM STORAGE BUILDING
26. SOLIDIFIED MATERIAL CONVEYOR
27. DRUM CONVEYOR
28. INCINERATOR STACK
29. AUXILIARY BOILER STACK
30. EVAPORATOR STACK
31. PIPERACK
32. TEMPORARY TRUCK HOLDING AREA (ORGANIC)
33. TRUCK HOLDING AREA (ORGANIC)
34. TEMPORARY TRUCK HOLDING AREA (INORGANIC)
35. TRUCK HOLDING AREA (INORGANIC)
36. CAR PARK
37. EMERGENCY ROAD, HYDRO & GAS CORRIDOR
38. LANDFILL STORM DETENTION POND
39. METEOROLOGICAL/AIR MONITORING STATION
40. RECYCLE WATER POND
41. EVAPORATOR FEED POND
42. TRUCK LOAD OUT STATION
43. TRUCK WASH STATION
44. TRUCK WASH STATION (FUTURE)
45. EVAPORATOR/RECYCLE PUMP HOUSE
46. FUEL OIL TANKS
47. EFFLUENT STORAGE TANKS

GENERAL NOTES

1. LOCATION OF ROADS & PROPERTY LINES TO BE FINALIZED FOLLOWING CONFIRMATION BY AERIAL AND/OR LEGAL SURVEY
2. CORE ZONE IS DEFINED AS AN ENVELOPE 400m FROM THE SITE BOUNDARIES, AS ESTABLISHED BY OWMC
3. RAIL CORRIDOR NOT SHOWN
4. SIZE & LOCATION OF LANDFILL STORM DETENTION POND TO BE CONFIRMED
5. EXACT LOCATION OF LANDFILL ACCESS ROAD TO BE DETERMINED

FIGURE 17
SITE PLAN

WNC000226

Postulates

- The area available for landfilling consists of all of the area surrounding the Central Operating Area on the site with the exception of the requirements for the storm water management pond, access and service corridors, and buffer zones.

4.2.5 LEACHATE QUANTITIES

The premises and postulates concerning leachate quantities are presented below.

Premises

- An estimate of the maximum potential quantity of leachate from the landfill assuming active operation has been provided by GLAL in order to evaluate the leachate transmission system (Ref: GLAL[5]). The estimate is based on the average precipitation at the Welland recording station less the following values:

  - soil moisture storage
  - evapotranspiration losses
  - minimum spring runoff

  Based on the above considerations, the resulting infiltration rate is 137 mm/year. This is a conservatively high estimate since runoff is taken into account only for spring (i.e. other annual precipitation events were assumed not to produce runoff from the landfill site).

Postulates

- Active operation of the leachate collection system will be assumed for the purpose of the leachate transmission system design and evaluation.

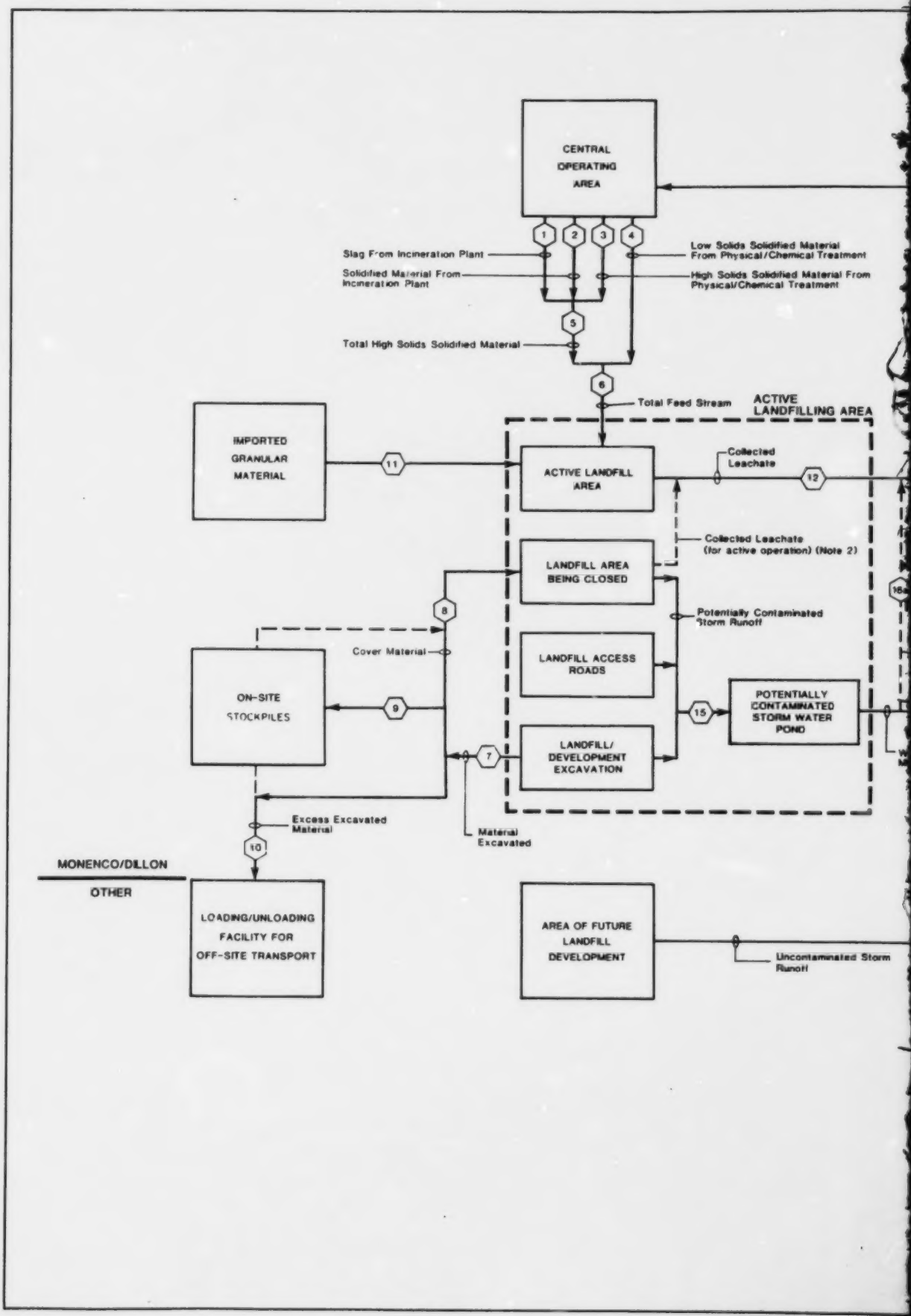
4.3 DESCRIPTION OF LANDFILL SYSTEM AND SERVICES

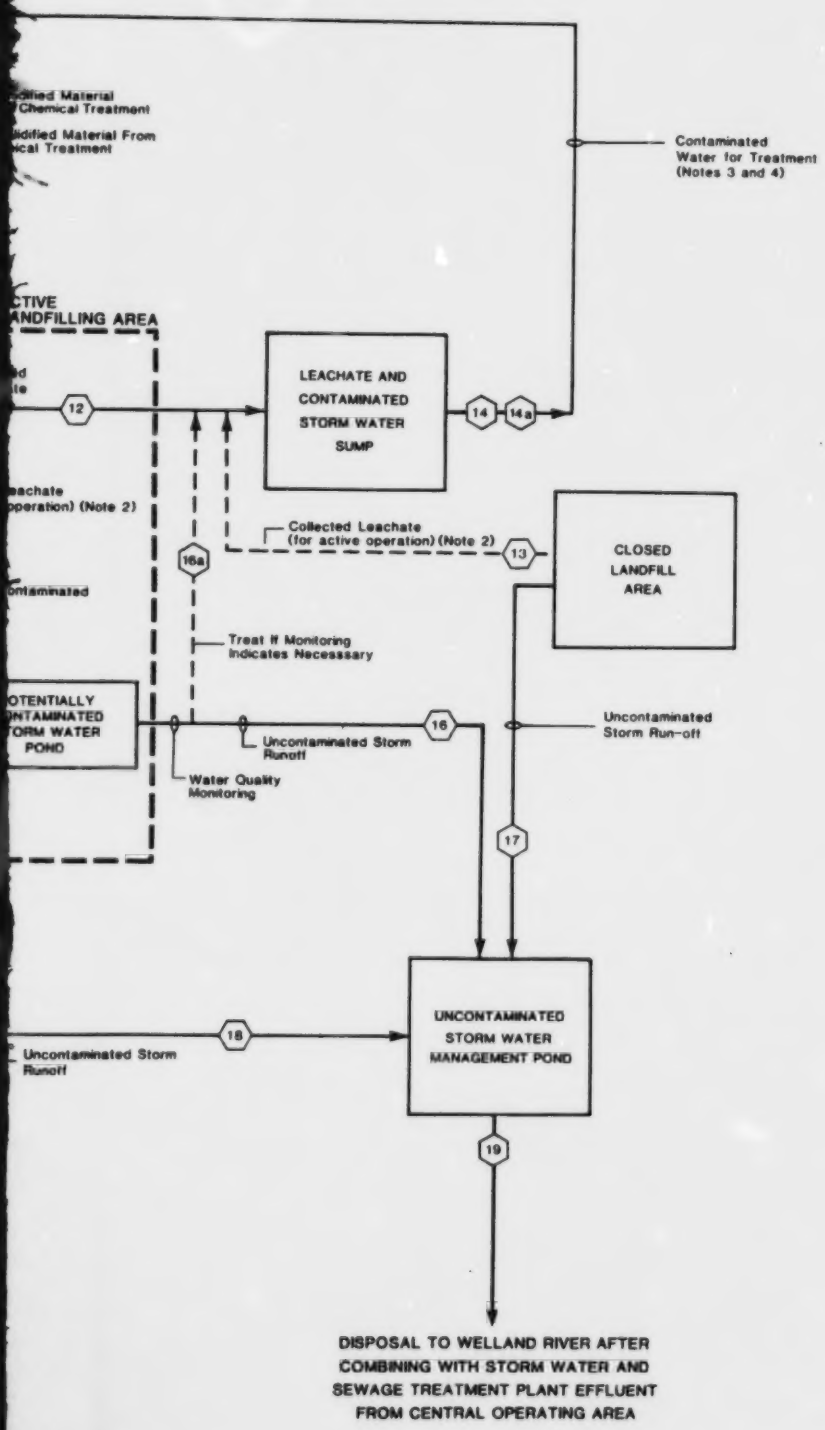
4.3.1 INTRODUCTION

The purpose of this section is to describe the major elements of the landfill system including dimensions, flow quantities, layouts and drawings. These elements form the framework for discussion of landfill development and operations, in Section 4.4.

Several references are made within this section to the Engineered Landfill Block Flow Diagram (shown in Figure 18). This drawing provides an overview of the interaction of the elements of the landfill. The drawing also indicates the flow quantities to/from the COA and to/from off-site. The major flow streams identified on the flow diagram are listed below:

- feed streams of solidified material for landfilling;
- leachate;
- storm water runoff: - potentially contaminated
  - uncontaminated;
- excavated clay material: - cover
  - stockpiling
  - off-site disposal
- effluent for discharge to the environment;
- imported granular material.


CENTRAL OPERATING AREA
1
2
3
4
Slag From Incineration Plant
Solidified Material From Incineration Plant
Low Solids Solidified Material From Physical/Chemical Treatment
High Solids Solidified Material From Physical/Chemical Treatment
5
Total High Solids Solidified Material
6
Total Feed Stream
ACTIVE LANDFILLING AREA
IMPORTED GRANULAR MATERIAL
11
ACTIVE LANDFILL AREA
Collected Leachate
12
Collected Leachate (for active operation) (Note 2)
LANDFILL AREA BEING CLOSED
8
Potentially Contaminated Storm Runoff
Cover Material
LANDFILL ACCESS ROADS
ON-SITE STOCKPILES
9
POTENTIALLY CONTAMINATED STORM WATER POND
15
7
LANDFILL/ DEVELOPMENT EXCAVATION
Excess Excavated Material
Material Excavated
10
MONENCO/DILLON
OTHER
LOADING/UNLOADING FACILITY FOR OFF-SITE TRANSPORT
AREA OF FUTURE LANDFILL DEVELOPMENT
Uncontaminated Storm Runoff



NOTES:

1. Initially the excess excavated material will be used in the construction of a perimeter berm. The estimated volume of excavated material required for the berm construction is 297,000m3. After completion of the berm, the excess excavated material will be disposed of off-site as indicated on the flow diagram.
2. If an active operation of leachate collection system is adopted, collected leachate will be transported to the central operating area for treatment.
3. Flows for 14 do not include any flows from the potentially contaminated storm water pond.
4. Flows for 14a include flows from the potentially contaminated storm water pond where monitoring indicates treatment is necessary.
5. In addition to the imported granular material, small quantities of other construction materials will also be required.
6. Uncontaminated flows as determined by monitoring.

REV	DESCRIPTION	DATE	BY	DILLON	MONENCO
				APPROVALS	

REVISIONS

M.M. DILLON LIMITED
for
MONENCO LIMITED

DESIGN MKS	OWMC TREATMENT FACILITY ENGINEERED LANDFILL
DFTG LJY/DEJ	
CHKD	
APP'D	
SCALE None	BLOCK FLOW DIAGRAM
DATE July 1986	

MMD PROJ. NO. 1022-50-2
MNC W.O. NO. 8084-2
REG. NO. 200790

DWG. NO. FIGURE 18 REV A

4.3.2 LANDFILL ROADS

Landfill roads play an essential role in several primary activities of the landfill. They are used for:

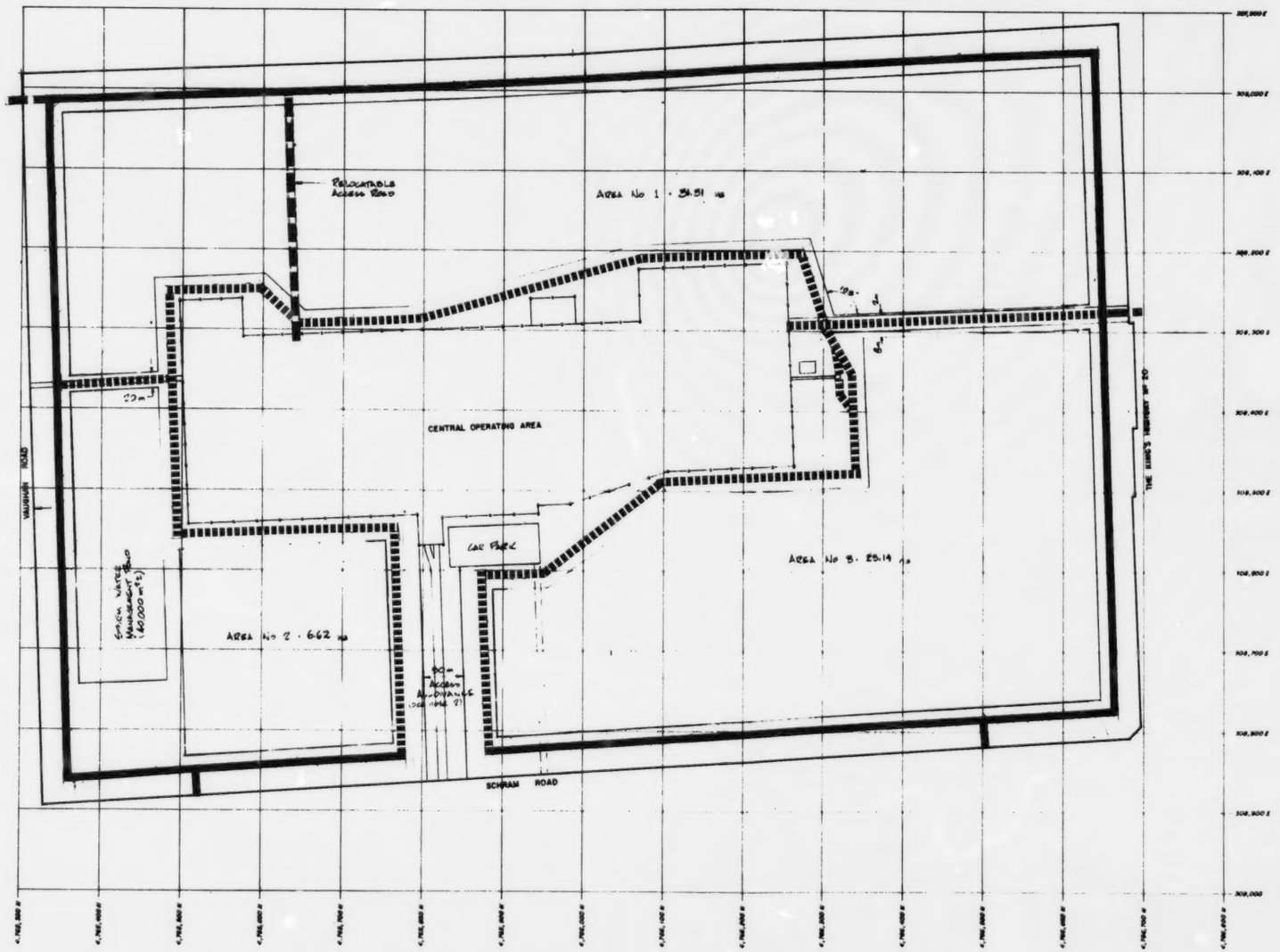
- haulage of excavated material to stockpiles;
- trucking of high solids solidified material to the working face;
- delivery of materials for underdrain construction;
- export of excess excavated material.

This section provides an overview of the network of roads necessary for landfill development and operation. It will be referenced in following sections discussing the above activities and related features of the landfill design.

Landfill roads are classified as permanent and temporary. Permanent roads will be designed to serve for the life of the Facility and for all-weather travel. One permanent road, called the perimeter road, will be constructed around the site perimeter inside the perimeter buffer zone. It will break only at the main access road to the COA. Internal roads, also permanent, will ring the COA, intercepted again by the main access road, and connect to the perimeter road. Figure 19 on Page 100 shows these roads.

Permanent roads will be paved for:

- long service life of the travelled surface;
- ease of cleaning of clay (to control tracking and dust) or solidified material (to control contamination);
- ease of snow removal.



NOTES:

1. CENTRAL OPERATING AREA LIMIT AND PERIMETER BOUNDARY ARE BASED ON MONENCO DWG. 00650007 - REV. 3.
2. 50m ACCESS ALLOWANCE PROVIDES 20m FOR THE PLANT ACCESS ROAD AS REQUESTED BY MONENCO (MEMO 07 JULY 1988) AND 30m FOR THE LOCATION/RELOCATION OF THE CAR PARK ACCESS ROAD.

LEGEND

- PERIMETER ROAD
- INTERNAL ROADS
- EMERGENCY ACCESS

REV	DESCRIPTION	DATE	BY	DILLON APPROVAL
A	ISSUE FOR INFORMATION AND COMMENTS	31 7 88		

REVISIONS

M.M. DILLON LIMITED
for
MONENGO LIMITED

OWMC
TREATMENT FACILITY
ENGINEERED LANDFILL

LF 9C
LANDFILL ROAD LAYOUT

DWG. NO. FIGURE 19 REV A

Temporary roads will depart from the permanent roads to provide access to the current working area for landfill operations. These roads will also be designed for all weather travel, however, they will not be paved. Temporary roads will be relocated as necessary to service the working area.

Access from off-site roads to the landfill roads will be provided at two locations, on Schram Road as shown on Figure 19. The access points will allow export of excess excavated material and import of underdrain construction materials. These will be the only access points for landfill operations use.

There are two other access roads off Schram Road. One is the main access to the COA and is limited in use to incoming waste vehicles. The other access road leads to the employee/visitor car park. Neither of these two roads are connected with the landfill road network.

In addition to the main COA access road there are two secondary access roads, from Highway 20 and from Vaughan Road. These roads are for emergency access to the COA and for access to the site meteorological/air monitoring station. Though they connect with the landfill roads, the access points will not be used for regular landfill traffic. The two emergency access routes provide the only two connections of the landfill roads to the COA.

4.3.3 AREA AVAILABLE FOR LANDFILLING

Introduction

In Chapter 3 of this report an evaluation of landfill development methods established the area method for the OWMC Engineered Landfill. The area surrounding the COA will be landfilled with the exception of a number of physical constraints, or areas which cannot be landfilled.

The major landfilling constraints are identified below:

- perimeter buffer zone
- internal servicing zone
- storm water management pond
- access roads/car park area.

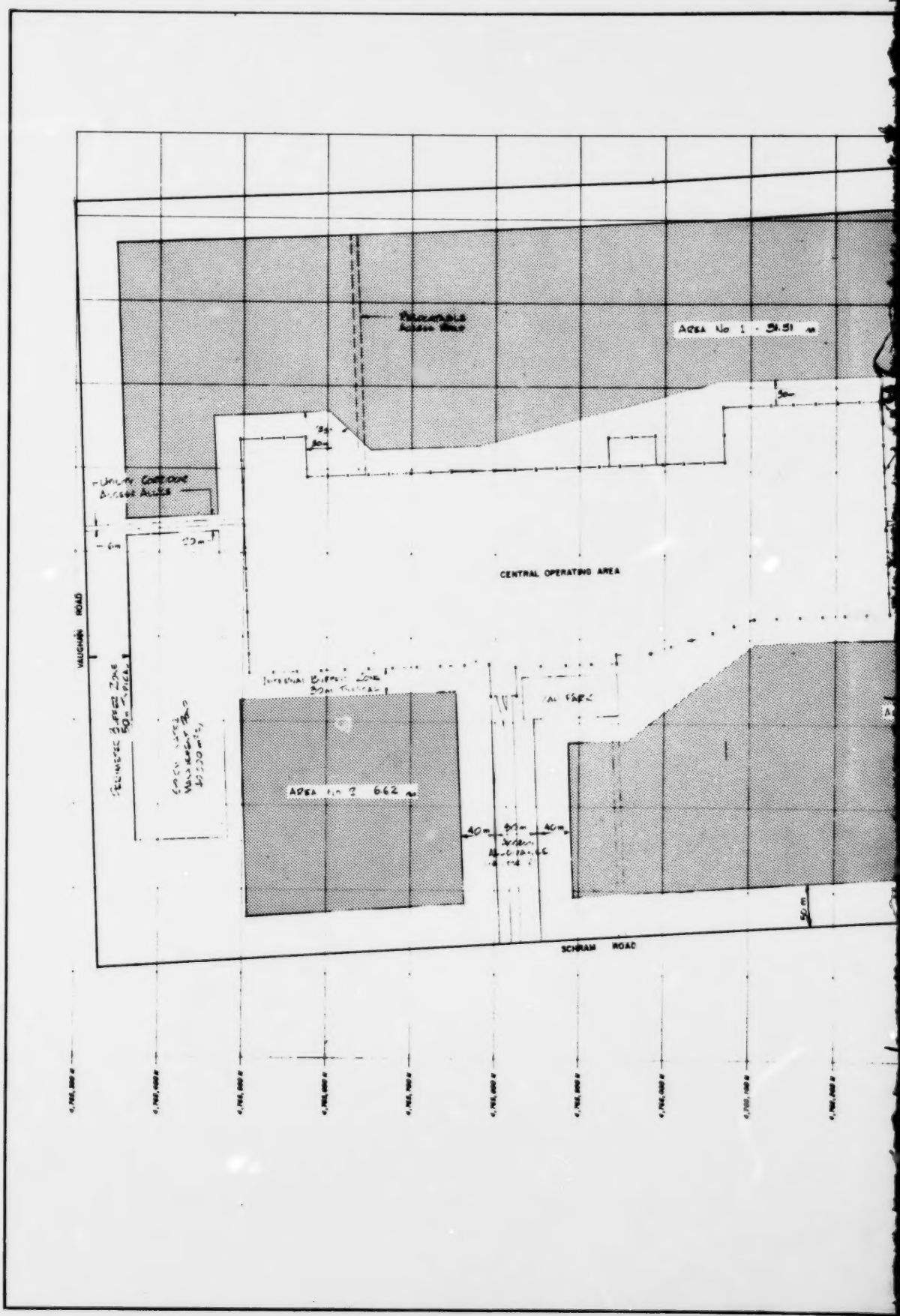
In addition to these major areas, some smaller areas which arise from the irregular geometry of the COA boundary are not considered to be practical for landfilling. Although not discussed below, these areas are shown on Figure 20 (Page 101).

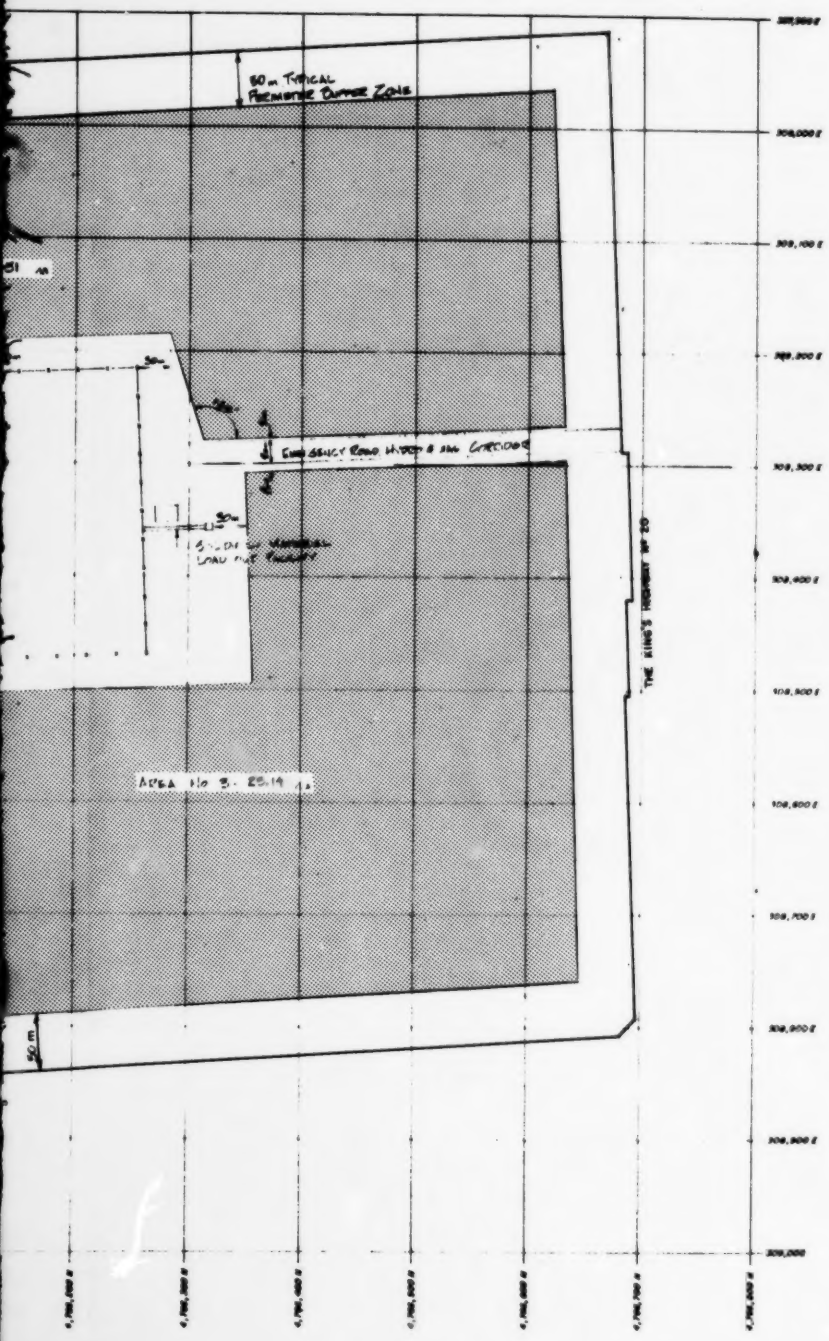
The following section provides documentation on the constraints to landfilling, including their functions and dimensions. The section is concluded with an estimate of the area available for landfilling.

Perimeter Buffer Zone

A buffer zone is required between the property line and the landfill development area for the following uses:

- installation of future contingency measures (if required);
- monitoring of environmental performance;
- access to landfill operations and to monitoring locations;
- drainage for the landfill and external areas;
- site security;
- visual and noise screening (if required).


Area No 1 - 31.51 ac
CENTRAL OPERATING AREA
VAUGHAN ROAD
SCHRAM ROAD
AREA No 2 662 ac
40m
50m



NOTES:

1. CENTRAL OPERATING AREA LIMIT AND PERIMETER BOUNDARY ARE BASED ON MONENCO DWG. 000500267 - REV. 0.

3. 50m ACCESS ALLOWANCE PROVIDES 20m FOR THE PLANT ACCESS ROAD AS REQUESTED BY MONENCO (MEMO OF JULY 1990) AND 30m FOR THE LOCATION/RELOCATION OF THE CAR PARK ACCESS ROAD.

REV	DESCRIPTION	DATE	BY	DILLON / MONENCO APPROVALS
A	ISSUE FOR APPROVAL AND COMMENTS	0-7-90		

REVISIONS

M.M. DILLON LIMITED
for
MONENCO LIMITED

OWMC
TREATMENT FACILITY
ENGINEERED LANDFILL

LF 9C
AREA AVAILABLE FOR LANDFILLING

FIGURE 20

REV A

A typical cross-section of the perimeter buffer zone is shown on Figure 21. The following briefly describes the features to be located in the perimeter buffer zone.

Contingency Measures. The main purpose of the buffer zone is to provide space between the landfill and the property boundary to allow for installation of contingency measures. Contingency measures could be located anywhere within the 50 m buffer width. The nature of the contingency measures will be established following impact assessment.

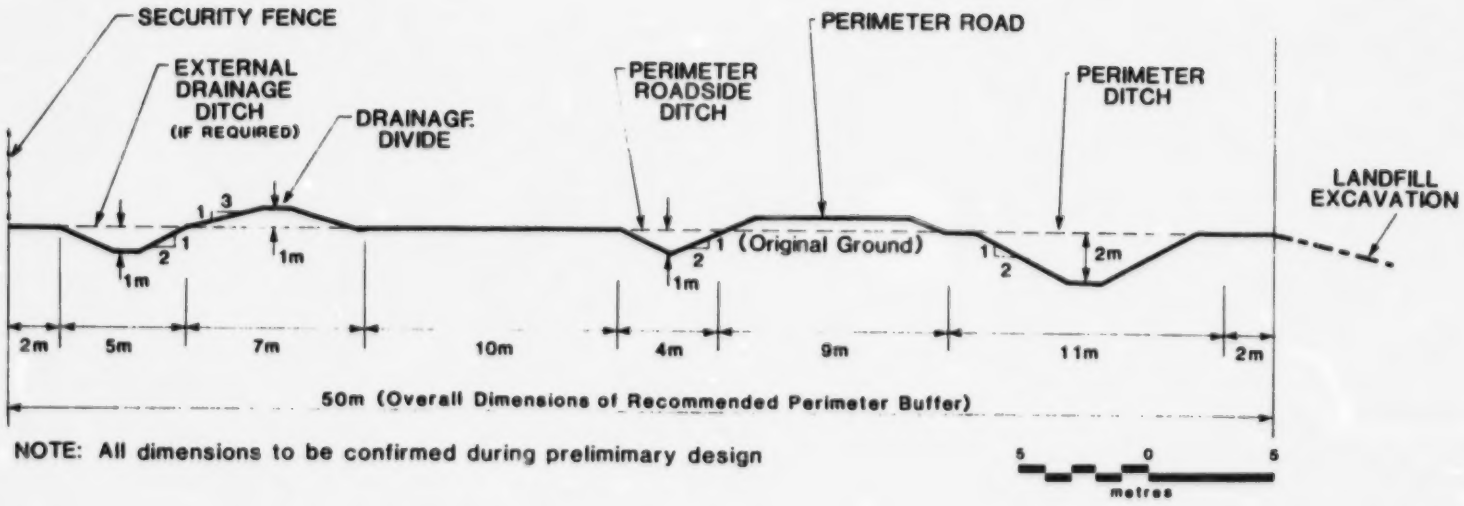
Monitoring Stations. Performance monitoring stations for air, ground water and surface water will be located in the buffer zone. Existing monitoring sites are shown on Figure 22.

Perimeter Road. A permanent landfill perimeter road is required for the landfill operation. A total width of 9 m (6 m wide travelled surface) is provided (refer to Section 4.3.2 for further detail on landfill roads).

Drainage Ditches. A perimeter ditch is provided to direct landfill surface drainage to the storm water management pond. A width of 11 m has been allowed for. The ditch width will be determined prior to issuing the final report.

Another ditch is required for site drainage on the other side of the road. This is known as the perimeter roadside ditch.

Finally, a 5 m width to allow for a drainage ditch to divert external drainage from around the site has been provided. This ditch would be located outside the drainage divide but within the security fence.



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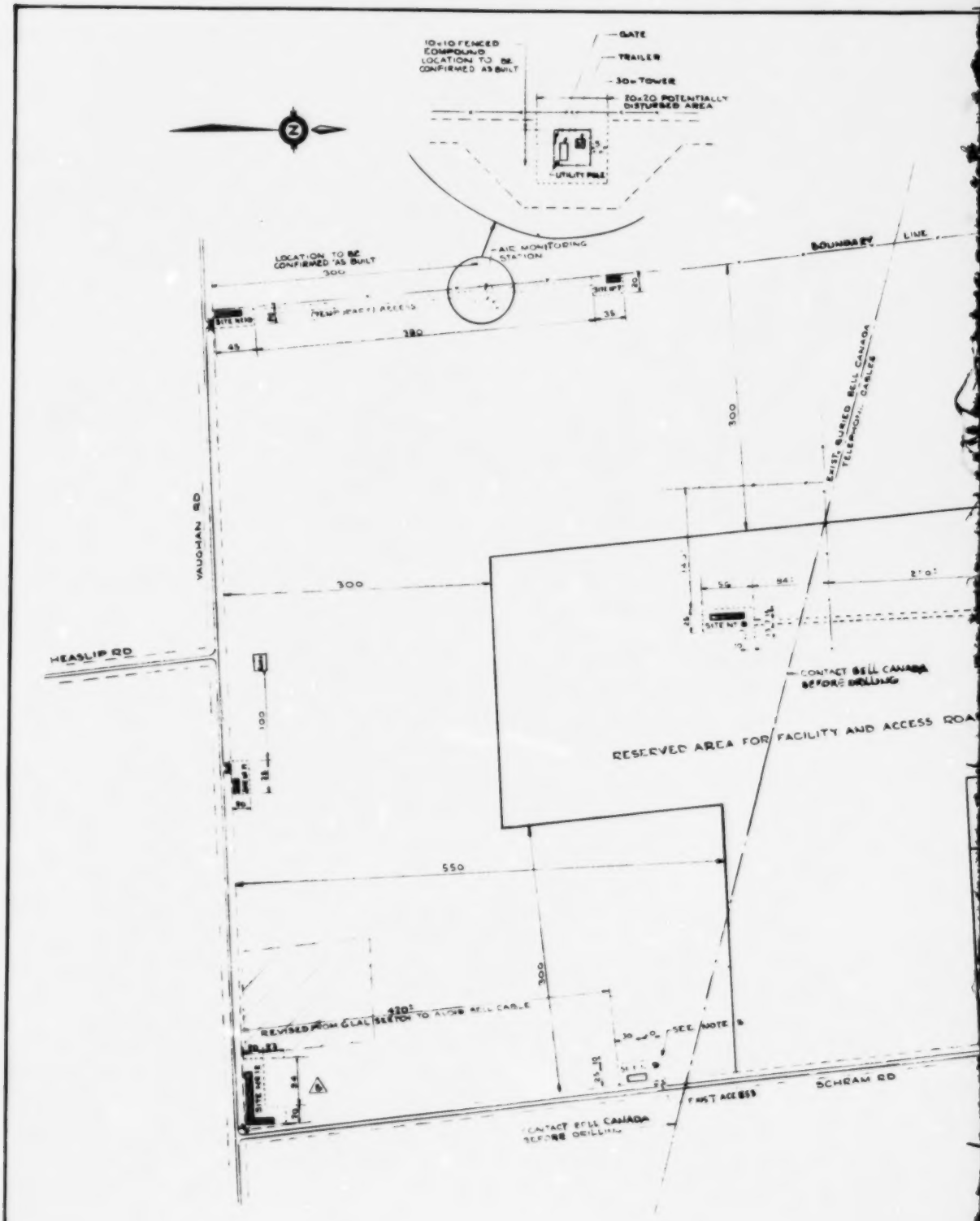
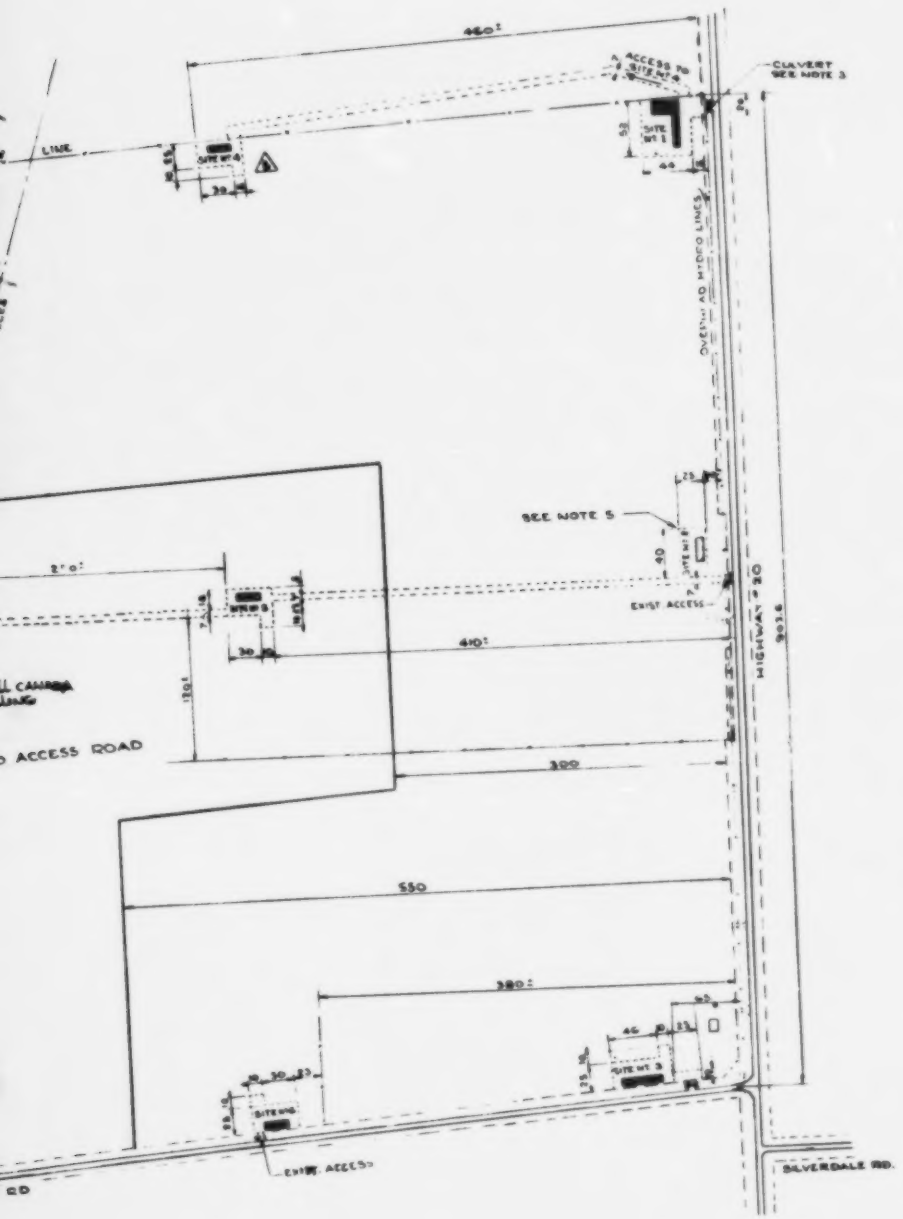
TYPICAL CROSS-SECTION OF PERIMETER BUFFER ZONE
FIGURE 21


10×10 FENCED COMPOUND LOCATION TO BE CONFIRMED AS BUILT
GATE
TRAILER
30m TOWER
20×20 POTENTIALLY DISTURBED AREA
UTILITY POLE
AIR MONITORING STATION
LOCATION TO BE CONFIRMED AS BUILT
300
BOUNDARY LINE
SITE N.W.P.
(TEMP. EXACT) ACCESS
35
180
45
300
EXIST. BURIED BELL CANADA TELEPHONE CABLES
VAUGHAN RD
300
MEASLIP RD
CONTACT BELL CANADA BEFORE DRILLING
RESERVED AREA FOR FACILITY AND ACCESS ROA
100
550
300
REVISED FROM GLAL SURVEY TO AVOID BELL CABLE
220'
SEE NOTE 5
SITE CENTRE
FIRST ACCESS
SCHRAM RD
CONTACT BELL CANADA BEFORE DRILLING



NOTES

1 ALL DIMENSIONS ARE APPROXIMATE UNTIL SURVEY COMPLETED

2 GLAL TO ADVISE OF ANY CHANGES TO MONITORING SITE LOCATIONS

3 CULVERT IN HWY 20 ROAD ALLOWANCE TO BE INSTALLED BY M.T.C. OTHERS TO BE INSTALLED BY TOWN OF WEST LINCOLN

4 BERMS AND PERIMETER DITCHES SHALL BE DESIGNED TO ACCOMMODATE FINALIZED LOCATION OF AIR MONITORING TOWER AND MONITORING SITES

5 MONITORING SITE LAYOUTS HAVE BEEN OBTAINED FROM G.L.A.L. SKETCHES (UNDATED) WITH MODIFICATIONS BY MONENCO TO THE FOLLOWING SITES : SITE NO 2 - RE ORIENTATED TO INCREASE LANDFILL AREA SITE NO 5 - RELOCATED TO AVOID BELL CABLES

6 MONITORING SITE NO 3 & 5 ARE ACCEPTABLE FOR CORE SAMPLING BUT NOT FOR PERMANENT MONITORING

7 MONITORING SITE NO 12 HOLD HAS BEEN REMOVED SEE G.L.A.L. LETTER FROM G.H. FUNK TO R. STUBY DWMC DATED 86-1-24

REFERENCE DRAWINGS USED AS BASIS

DWG NO	REV	TITLE
41729-SD	-	MTC. HWY 20 SURVEY - OCT. 1984
843080	-	BELL CANADA BURIED CABLES - 84-10-26
		G.L.A.L. - MONITORING SITE SKETCHES

MONENCO LIMITED

DWMC TREATMENT FACILITY

LF-2C LOCATION OF MONITORING SITES

W.O. No. 8.N.C.6.2.2 - 2

DWG. No. 2-1-2 CORE 2.1

FIGURE 22

D

Drainage Divide. A 1 m high berm to isolate site drainage from external drainage will be constructed just within the property boundary. If required, this berm may be increased in size to provide, in addition, visual and noise screening.

Security Fence. An external security fence will be provided around the perimeter of the site.

Internal Servicing Zone (Between the COA and Landfill Area)

A servicing zone is required around the fenced-in operations area (COA) to provide physical separation between the two operating areas and to allow for roads, utilities and drainage.

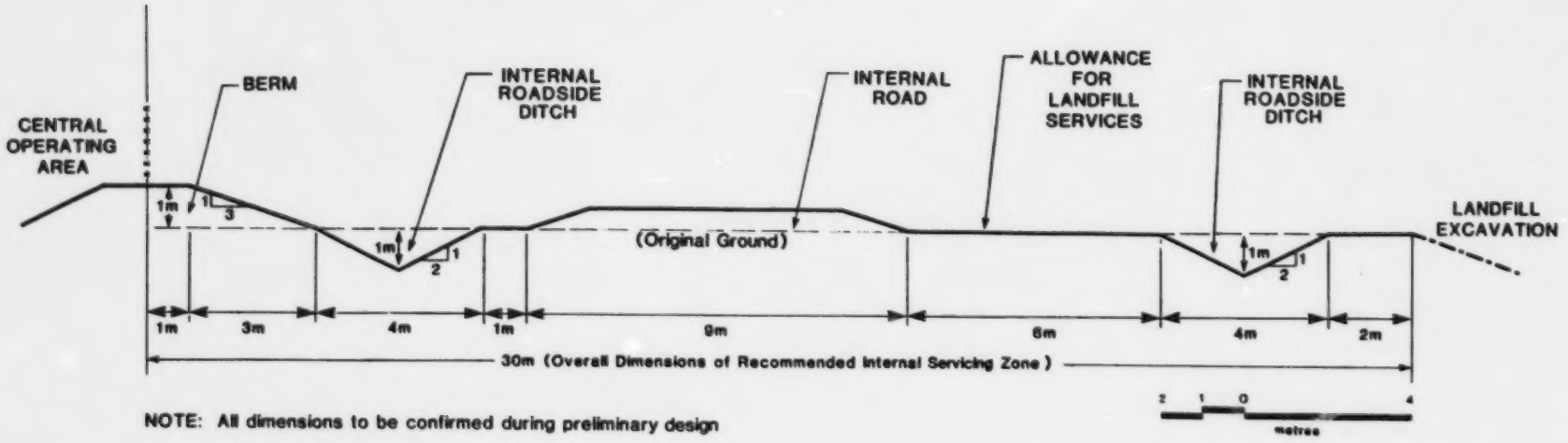
A cross-section of the zone is shown in Figure 23. The features within the internal buffer zone are described below.

Berm. The security fence around the COA will be located on a 1 m high berm with a top surface width of 2 m and 3:1 side slopes. The total width of the berm will therefore be approximately 8 m where 4 m contribute to the buffer zone. The purpose of the berm is to provide a drainage divide between the COA and the landfill.

Internal Road. A permanent internal road is provided in the servicing zone. This road will have access to the COA at two locations. Roadside drainage ditches (assumed 1 m depth and 2:1 side slopes), will be constructed on either side of the road as shown in Figure 23.

Utilities. A 6 m width has been provided as an allowance for the following services:

- A low solids solidified material slurry pipeline.
- Overhead hydro service and communication lines.
- A leachate transmission main.



NOTE: All dimensions to be confirmed during preliminary design

DILLON

TYPICAL CROSS-SECTION OF INTERNAL SERVICING ZONE
FIGURE 23

The total width required for the internal servicing zone is estimated at 30 m.

Storm Water Management Pond

The pond size is estimated at 40 000 m^2, located at the south end of the property.

Access/Utility Corridors

A discussion of the landfill roads in Section 4.3.2 provided their general layout and functions. The following section describes the access/utility corridors as they affect the area available for landfilling.

Raw Water Supply. A raw water supply pipeline and a storm sewer corridor will enter and exit the site from the south off Vaughan Road. A corridor width of 20 m has been provided to allow the flexibility for the construction of these utilities as well as to accommodate an internal road and associated drainage. This will also provide greater flexibility for servicing and maintenance of the adjacent storm water management pond.

Emergency Access Road, Electrical Transmission Line and Gas Corridor. An emergency access road, together with an electrical transmission line (pole line) and natural gas corridor for the COA, enter the site from the north off Highway 20. The location of the facilities are shown on Figure 20 (Page 101). The corridor width requirement is 20 m (Ref: Monenco Limited[6]), however, an additional 10 m has been provided to accommodate a slurry pipeline for transporting the low solids solidified material to the landfill, and a hydro supply for landfill operations. The emergency access road is an extension of the internal road through the perimeter buffer zone.

Main Entrance and Parking Area. The main entrance to the COA is from Schram Road on the east side of the site. The entrance will contain the following key features:

- plant access road
- scales to weigh vehicles entering and leaving the COA
- gate house
- separate entrance/exit and parking area for employees and visitors.

These features are identified on Figure 17 (Page 93).

A 20 m width is required for the plant access road including allowance for drainage (Ref: Monenco Limited[6]). The entrance/exit road to the car park is considered relocatable; therefore, will not be a constraint to landfill development. To provide an allowance for the plant access road and the relocation of the car park entrance/exit road, a 50 m corridor has been identified. In addition to this, a 40 m buffer on each side of this corridor is provided. The features within this buffer will be similar to those within the perimeter buffer zone, with the exception of the perimeter and external drainage ditches. This results in a permanent corridor, constrained from landfilling, with a width of approximately 130 m.

In addition to the above, a secondary COA access road which crosses the landfill from the air monitoring station is relocatable and therefore will not act as a constraint to landfilling.

Summary

Based on the above constraints, the area available for landfilling is shown in plan on Figure 20, Page 101. Three major blocks have

been identified from the plan as available area for landfilling. A summary of the individual and total areas of the blocks are listed below.:

Area 1	31.5 ha.
Area 2	6.6 ha.
Area 3	25.1 ha.
TOTAL AREA	63.2 ha.

Estimates of the site lives based on the total area of 63.2 ha are given in the following section.

4.3.4 LANDFILL SITE LIVES

The initial capacity for OWMC's treatment Facility is 150 000 tonnes of waste/annum with provision for future expansion to 300 000 tonnes/annum. Site lives have been calculated for both cases.

The operating scenario for the Facility will be dependent on the waste profile. The design basis for the landfill is the "Typical Operations Case" as defined previously. To provide a bracketing range for landfill site life estimates for other waste profiles, a sensitivity analysis has been carried out based on a "High Effluent Case" and a "High Solidified Waste Case". The resulting waste quantities for the various operating scenarios and waste inflow quantities is provided in Tables 11 and 12 in Section 4.2.2.

The area available for landfilling identified on Figure 20 (Page 101) and the excavation section shown in Figure 16 (Page 90), form the basis for the calculation of site lives.

Based on the foregoing, the landfill site life for the "Typical Operations Case" scenario with a waste inflow rate of 150 000 t/a is 37 years. As discussed above, site lives for variations in operating scenarios and waste inflow rates have been calculated as a sensitivity analysis. These are presented on Table 14.

4.3.5 SOLIDIFIED MATERIAL TRANSPORT

Two systems are necessary for the transport of solidified material from the COA to the landfill; one for high solids solidified material and one for low solids material. These systems are discussed separately below.

High Solids Material Transport

An evaluation of the high solids materials transport was carried out by Monenco Limited (Ref: Appendix E). A summary of the evaluation is presented below.

Two options were considered for the transport of high solids solidified material from the COA to the landfill working area.

- belt conveyor system; and
- dump trucks

Both the belt conveyor and the trucking options are widely used systems.

The two systems were evaluated based on an incoming waste stream of 150 000 t/a with an assessment of the necessary provisions for expansion to 300 000 t/a capacity.

TABLE 14

LANDFILL SITE LIVES

OPERATING SCENARIO	WASTE INFLOW RATE	
	150 000 tonnes/annum	300 000 tonnes/annum
High Effluent Case	75 years	41 years
Typical Operations Case	**37 years***	22 years
High Solidified Waste Case	23 years	15 years

*** Design basis for landfill.**

Notes:

- **The Typical Operations Case highlighted in bold print represent the expected operating scenario.**
- **The High Effluent Case and the High Solidified Waste Case represent the bracketing range of site lives provided as a sensitivity analysis.**

A number of criteria for evaluation were used. A trucking system was found to be the preferred system because of its greater flexibility and reliability, low interference potential with landfill operations and lower cost (Ref: Appendix E).

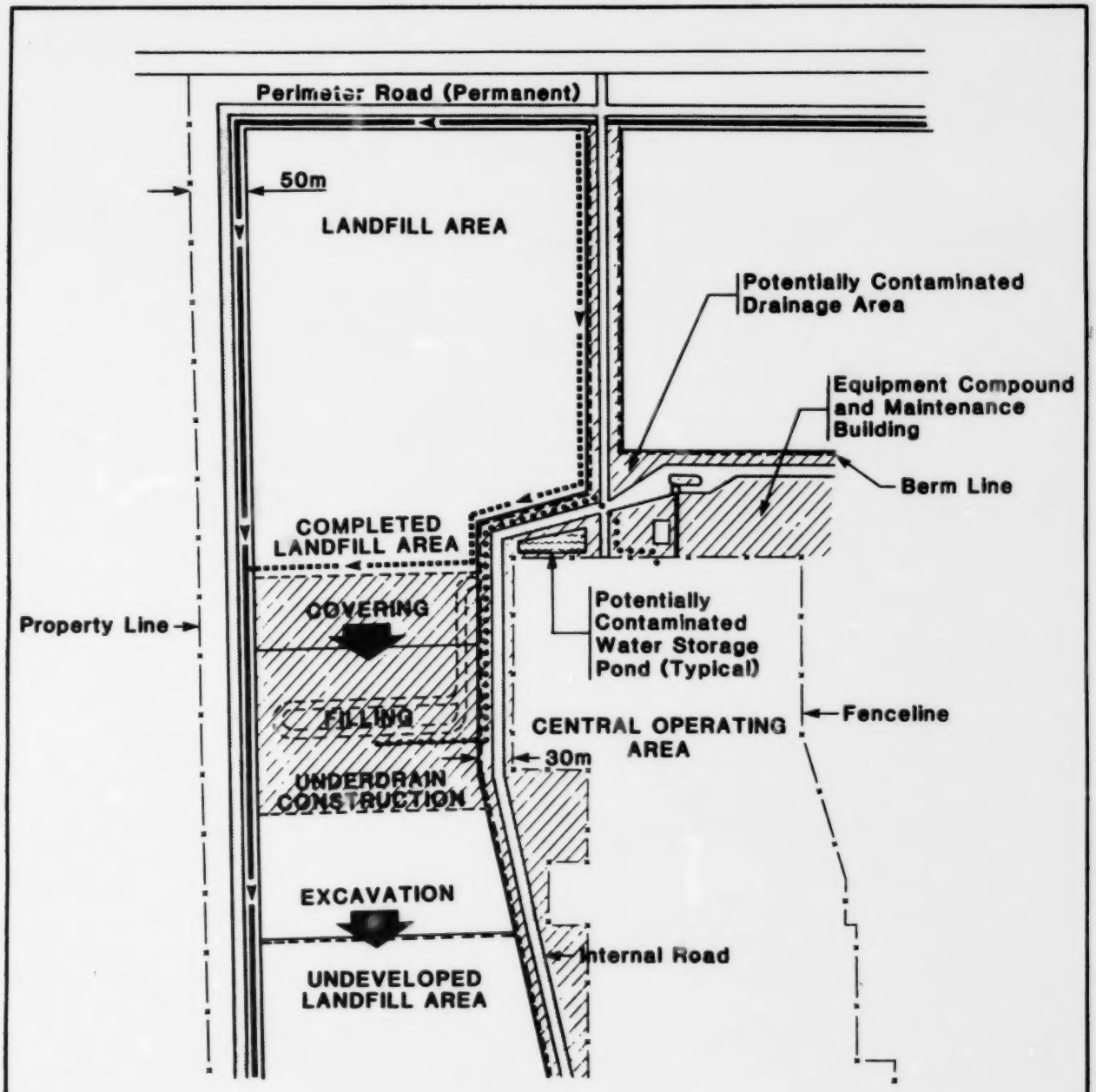
Solidified material for landfilling will be received in dump trucks at the load-out facility 5 days/week (250 days/annum, 8 hours/day).

Solidified material produced at the incineration process area and slag from the incineration plant will be transferred to the load-out area. It will then be transported with the other solidified material by truck to the landfill. The incineration facility operates 7 days/week, and therefore some slag and solidified material may have to be stored in the interim storage building on the weekends.

The dump trucks receiving the solidified material will travel from the load-out area, along the interior roads to the active landfill area. The trucks will then branch off onto a temporary access road and down the ramp into the excavation to the active lift. The trucks will end dump and drive out up the ramp of the excavation, back onto the interior road and return to the load-out area (Figure 24, Page 113).

The solidified material will be spread with a bulldozer and compacted by a compactor on the active lift.

All trucks moving solidified material will be used strictly for that purpose. Their travel will be restricted to the internal roads to avoid inadvertent transfer of solidified material and clay by tracking. The perimeter road will not be used by trucks carrying solidified material. The controls on traffic are discussed further in the section on Surface Water.



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LANDFILL OPERATIONS

FIGURE 24

Low Solids Pipeline

Approximately 25% of the solidified material (for "Typical Operations Case") will be of a low solids consistency. The consistency of this material after curing will be very similar to the high solids material; however, prior to solidification, it will be handled in a manner similar to that of a slurry. The proposed method for transport of the low solids material to the landfill is by a pipeline from the COA to the active landfilling area (Ref: Appendix E).

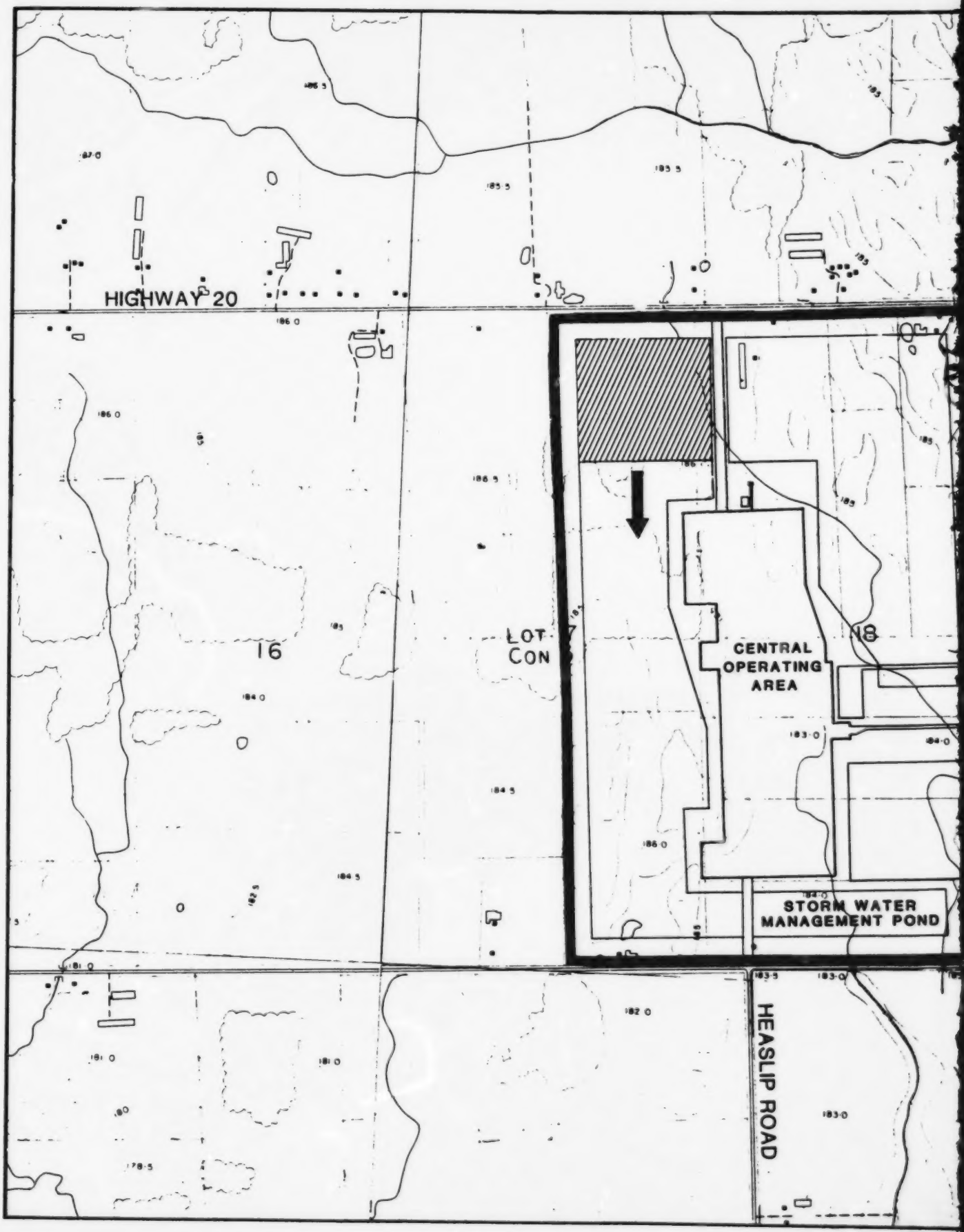
The pipeline will follow the interior roads to avoid disruption by landfilling activities. A moveable pipeline will be used to service the working area from the interior roads.

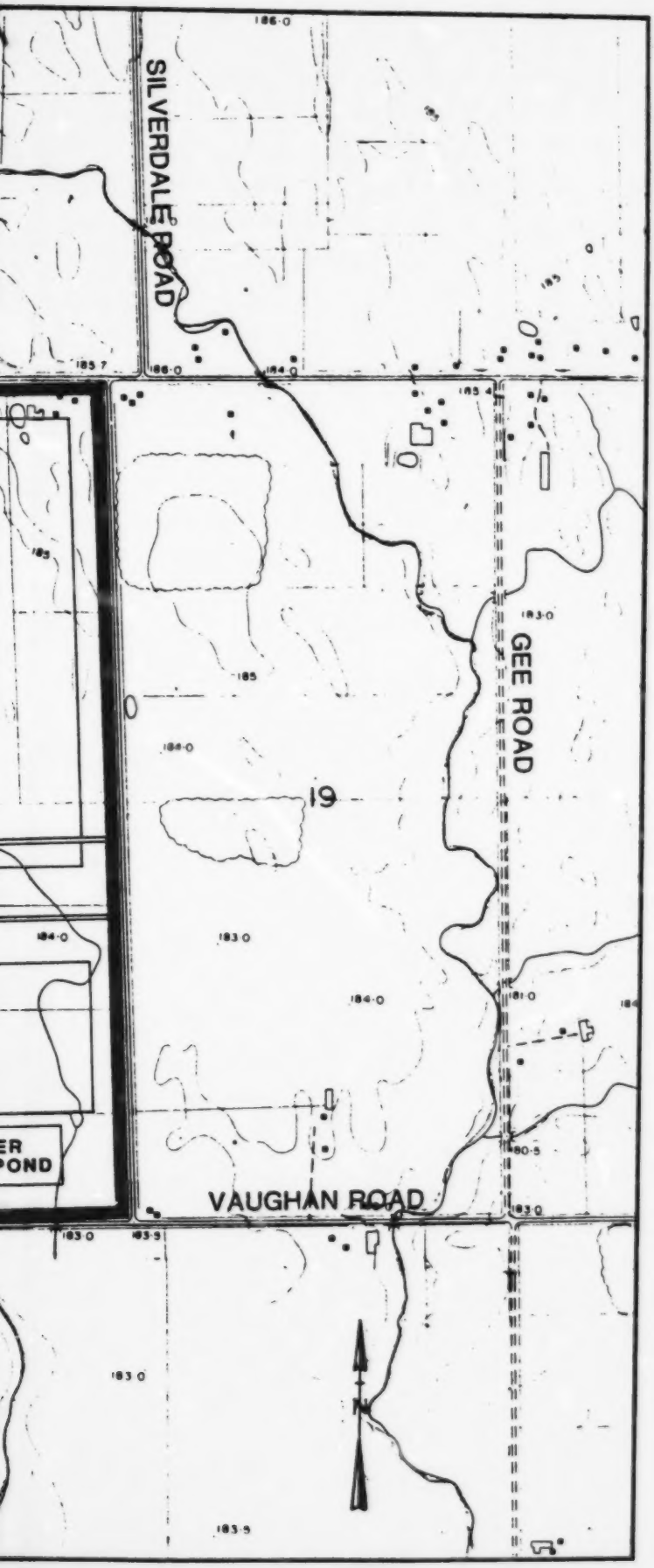
4.3.6 EXCAVATION AND EXCESS MATERIAL EXPORT

Introduction

The landfill design involves the placement of solidified material at depths between 5 and 15 m below grade. It is therefore necessary to excavate to a minimum depth of 15 m below grade. The side slopes are benched (average 1:4) as shown on Figure 16 (Page 90) to provide an adequate factor of safety against slope failure.

Before landfilling can begin, an initial excavation must be prepared (see Figure 25, Page 115). The size of the excavated area will remain relatively constant throughout the period of landfill development since the excavation face will advance, on average, at about the same rate as the working face. The working face is expected to advance more or less continuously throughout the year in keeping with solidified material production. Excavation, however, will be limited to about six months of the year (typically May to October) because of difficulties due to wet or frozen ground conditions.


HIGHWAY 20
16
LOT
CON
18
CENTRAL
OPERATING
AREA
STORM WATER
MANAGEMENT POND
HEASLIP ROAD



OWMC Ontario Waste Management Corporation

Consultant

DILLON
Consulting Engineers & Planners

Legend: **LF - 9Central**

Direction of Landfill Advancement

Initial Landfill Development

Acquisition Boundary

0 1000 feet
0 500 metres
1:10 000

INITIAL LANDFILL DEVELOPMENT AREA

JULY 1986
(Based on Dec.1985 Original) **FIGURE 25**

The excavation face will therefore advance more quickly than the working face during the summer months to accommodate the interruption of excavation over the winter months.

The movement of excavated material has three possible routes as indicated on the Block Flow Diagram (Figure 18, Page 96). These routes are listed below:

- to the landfill area being closed for use as cover material;
- to the loading/unloading facility for off-site transport;
- to on-site stockpiles for future use as cover material or off-site transport.

Imported Materials

The initial development and ongoing operation of the landfill will require the import of various materials including:

- Granular materials for road and underdrain construction.
- Manhole sections for underdrain sump risers.
- Materials and equipment for leachate collection, pumping and transmission.
- Operations and maintenance equipment and materials.

Beyond the initial development period, the largest number of vehicles (for materials import) will be used for the importing of granular materials for the underdrain construction.

Excess Clay Material

The shallow entombed landfill generates more excavated clay than is required for final cover or berm construction. As a result it will be necessary to dispose of clay material.

On-site disposal of clay other than for berm construction and contouring for surface drainage, is not recommended. This is based on a concern that additional fill above-ground level will impact the hydrogeologic performance of the shallow entombed landfill (Ref: Appendix C). Excess clay material, must therefore be disposed of off-site.

Landfill development will include excavation for the initial landfill area, the storm water management pond and ditches. Some of this excavated material will be consumed for the construction of on-site berms. The balance will be transported off-site.

After completion of the initial development, excess excavated material will have to be removed off-site on a continuous basis. Though excavation occurs in only half of the year, it may be desirable to distribute off-site removal more evenly throughout the year. The quantities of excess material will be a reflection of the amount of solidified material requiring disposal. The projected solidified material quantities are given in Section 4.2.2.

4.3.7 SURFACE WATER

Introduction

Surface water will be managed as being either:

- uncontaminated; or
- potentially contaminated.

Drainage zones will be designated in the landfill according to how surface water is managed. The definitions for and identification of the drainage zones, and description of the management measures are provided below.

Uncontaminated Surface Water

Uncontaminated runoff will originate only from areas where drainage has no opportunity to contact the solidified material. The zone where water will be managed as uncontaminated includes:

- undeveloped areas;
- completed areas of the landfill; and
- the excavation face of the landfill excavation.

No contaminated runoff is expected from undeveloped areas as there will be no solidified material handling there. Similarly, in completed areas solidified material handling will have halted and the solidified material will be covered by 5 m of compacted clay. The drainage from the excavation face of the landfill will be separated from the active fill area and underdrain construction area by a berm on the landfill base. Drainage from the excavation area will therefore have no opportunity to contact solidified material or other drainage that may have contacted the material.

Uncontaminated surface water flows will be controlled for peak flow reduction but not for storage and testing.

Potentially Contaminated Surface Water

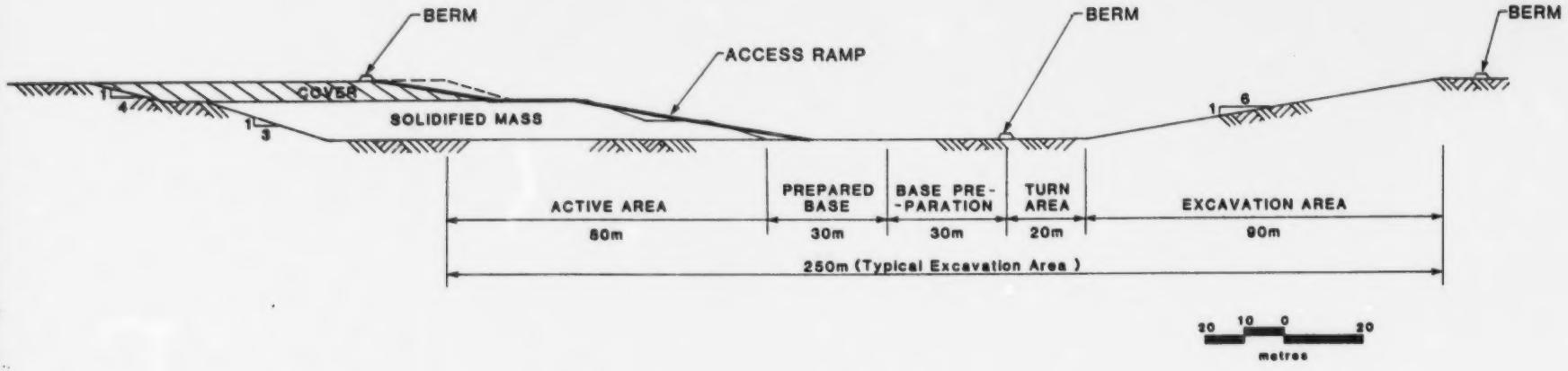
A premise for landfill design was that contaminants released from the solidified mass could produce a leachate quality of concern over a period of time measured in hundreds of years. Accordingly, provision has been made for leachate collection and treatment. The underdrain would be actively operated only if leachate quality analysis and environmental monitoring determines it is necessary.

A similar approach will be used in the management of surface water. Surface water that comes in contact or may come in contact with solidified material will be considered potentially contaminated. It will be collected and tested to determine if it is uncontaminated or contaminated. If uncontaminated, it will be discharged to ditches draining to the storm water management pond. If contaminated, it will be sent to the physical/chemical treatment plant for treatment or to the leachate collection system.

Surface water may contact the solidified material in the active fill area. It will be collected in either the leachate collection sumps or in temporary sumps in the active fill area for testing. As mentioned previously, a berm will divide the excavation, separating runoff from the area of filling and underdrain construction from the excavation face (see Figure 26, Page 120).

If uncontaminated, the water will be pumped to surface to the perimeter or internal ditches. If contaminated, it will be handled as leachate. Under passive operation, leachate will not be removed from the collection system unless it interferes with filling or underdrain construction. If the collection system is actively operated, or if leachate removal is required for construction reasons, the leachate will be transmitted to the physical/chemical treatment plant for treatment.

Surface water may also contact solidified material outside the active fill area if material is tracked from the active fill area by equipment, or if spillage occurs at the load-out area or along the low solids slurry pipeline. This water will be collected by internal roadside ditches and carried to potentially contaminated water storage ponds located along the internal road adjacent to the COA. It will be tested prior to discharge. As



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PROFILE THROUGH LANDFILL WORKING AREA

FIGURE 26

before, uncontaminated water will be discharged to the internal ditches. Contaminated water will be transmitted to the physical/ chemical treatment plant for treatment. The means of transmission is described in Section 4.3.8.

The potentially contaminated drainage zone therefore consists of:

- the active fill area;
- the loadout area; and
- the internal roads

Travel Between Drainage Zones

The two zone drainage designation carries implicit restrictions on travel between zones. Because of the mechanism of tire tracking of solidified material, travel from the potentially contaminated zone to the uncontaminated zone is not possible without potentially spreading contamination.

There are a number of instances where landfill traffic must move from the uncontaminated zone to the potentially contaminated zone. An example would be the import of granular material for underdrain construction. Trucks must come from off-site (uncontaminated) and enter the excavation at the active fill area (potentially contaminated) to unload before returning off-site. Another instance is the delivery of clay from the excavation face or stockpile (both in the uncontaminated zone) to the active fill area.

To avoid contamination transfer, two possible solutions have been identified: materials transfer; and truck wash. The first involves isolating vehicle traffic within the potentially contaminated zone from the uncontaminated zone. Off-site vehicles

carrying imported material or scrapers hauling clay for cover would have to transfer these loads to landfill vehicles at the uncontaminated zone boundary. This introduces the delays and expense of double handling. The second solution is to provide a truck wash for vehicles leaving the potentially contaminated zone. Drawbacks, however, are the delay to traffic and the wash water volume to be treated.

These controls will be evaluated and the preferred measure selected for the final report.

Drainage Design

The surface drainage section of the final report will describe the purpose and basic objectives to be met by the surface drainage system. It will also indicate that drainage under existing, interim and post-development conditions will be analyzed.

The proposed post-development drainage system and components will be described. Adjustments to model parameters for modelling post-development flows will also be described. A discussion of the sensitivity of post-development flow estimates to the various parameters will be included.

The existing and post-development flow estimates will be tabulated for comparison purposes, and conclusions drawn regarding the impact of the development.

The conceptual design of the various system components will be presented. These components include:

- grading
- perimeter and internal ditches
- culverts
- storm water management pond; and
- outlet

Appropriate design data (flow estimates, velocities, depths, etc.) will be summarized.

The last major item to be included in this section concerns interim drainage conditions (prior to completion of landfilling). The need for berming around active landfilling areas, potentially contaminated storage ponds and adequate erosion control measures on-site will be addressed.

4.3.8 LEACHATE TRANSMISSION TO TREATMENT FACILITY

Underdrain Design

The development and rationale for the system of devices for control of ground water contaminants were given in Chapter 3. The proposed system of devices for the shallow entombed concept is the native clay base, simple cover and an underdrain leachate collection system.

The design of the leachate collection system at the conceptual engineering level, will be based on active operation.

Due to the lack of grade across the site, a number of leachate collection sumps will be required, with each sump collecting drainage from a local area. The sumps will be located within the landfill. Risers to ground surface will allow access. Leachate will be pumped from the sumps to the leachate transmission system through pipes leaving the sump risers near ground surface.

Three underdrain design alternatives are presently being considered. These are:

- blanket drain (no pipes);
- blanket drain with a pipe collection around the landfill base perimeter; and
- blanket drain with a network of pipes across the entire base.

In addition, two alternative materials for the underdrain blanket, granular and synthetic drainage net, are being considered.

The criteria established for evaluation of the landfill features by Monenco Ltd. will be used for evaluation of the underdrain alternatives. Sub-criteria which reflect specific objectives under each criteria pertinent to the underdrain evaluation will be developed. The evaluation will be used to select the proposed design alternative for the final report.

Leachate collected from the underdrain system will be monitored and treated, if required, by the physical/chemical plant in the COA. In addition to leachate quantities from the landfilled area, there may be some contribution from the potentially contaminated drainage zone. The potentially contaminated zone includes the load-out area and the internal landfill roads. Surface runoff from these areas will be collected in potentially contaminated water storage ponds and monitored. If treatment is necessary, the runoff will be transported to the COA. (See Figure 18, Page 96.)

A comparative evaluation of options for transporting leachate and contaminated flows to the COA was undertaken (Ref: Appendix F).

The following describes the process and criteria used to select the preferred option.

- Transport by truck - This would involve tanker trucks for delivery of the leachate from the landfill to the COA. Leachate would be collected from several locations including:

  - underdrain collection sumps;
  - potentially contaminated pond (if monitoring indicates treatment is necessary); and
  - temporary sumps in the active working area.

  Alternatively, all flows could be discharged to the leachate system and collected from the underdrain sumps.

- Transmission by pipeline - This would involve a permanent pipeline (forcemain and/or gravity sewer) from the landfill to the COA. The pipeline would transmit flow from sumps in the underdrain system to the COA. Flows from the potentially contaminated water storage ponds and temporary sumps in the active landfill working area could be either discharged to the underdrain system, or pumped, using temporary pumps into the leachate transmission system.

The evaluation of the leachate return options found a pipeline system to be the preferred mode of leachate transport.

In terms of safety, a pipeline is preferred since it will minimize the potential for spills through reduced handling. In the unlikely event of a pipeline leak, the leachate collection system will minimize environmental impact. A trucking system, on the other hand, has the potential for spills during loading and unloading of the trucks. A spill during trucking has the potential to contaminate the surface water, since trucking operations are carried out above-ground.

Other benefits of a pipeline system include much lower capital and operating costs, compared to trucking. Trucking results in high costs because of time required for loading and unloading, relative to the travel time.

4.3.9 LANDFILL COVER

The proposed system of devices for the shallow entombed landfill concept included a simple cover of 5 m of compacted clay.

The proposed mode of operation is passive unless analysis of the leachate quality, environmental impacts and hydrogeologic performance of the landfill necessitates active operation.

Under passive conditions, the rate of infiltration into the landfill is largely controlled by the clay underlying the landfill. However, the grading of the cover also has an impact on infiltration. In the initial concept, the cover was assumed to be flat. From a hydrogeologic standpoint, the absence of surface relief is desirable as the head for the aquifer pathway is minimized. However, a flat site is inefficient from a surface drainage standpoint and provides no opportunity for on-site disposal of excess excavated material.

Four cases of cover grading were developed for evaluation. In brief, these are:

Base Case
- final cover topography simulates natural site relief
- 2% grades
- ridges at 100 m spacing
- 1 m maximum relief

Case 1
- 4% grades with a single drainage divide at centre of the landfill
- average crest height 4.5 m (maximum 5.6 m)

Case 2
- 4% grades with two drainage divides
- collector ditch down centre of landfill
- average crest height 2.25 m (maximum 2.8 m)

Case 4
- 2% grades with two drainage divides
- collection ditch down centre of landfill
- average crest height 1.1 m (maximum 1.4 m).

A comparative evaluation will be undertaken. Three key criteria will be:

- hydrogeologic performance;
- hydrologic performance; and
- operations (excess material export).

This evaluation will be presented in the final report.

4.4 LANDFILL SITE DEVELOPMENT AND OPERATION

4.4.1 INITIAL LANDFILL SITE DEVELOPMENT

The initial landfill site development tasks and staging for preparation to begin landfill operations will be described in the final report. The documentation will be centred around the following key areas.

Rationale for Starting Point

- Provide an assessment of the proposed initial area of landfill development and operations taking into account the following considerations:

  - geotechnical concerns;
  - operations;
  - drainage;
  - potential impact of future decision to provide a rail spur line into the COA.

Staging and Implementation Schedule

A staging and implementation schedule for initial development and ongoing landfill operations will be contained in the final draft of the PAR. The purpose of the schedule is to identify the order and time frame required for the construction activities. The staging schedule and/or plan will indicate anticipated areas and timing for landfilling operations.

The schedule for initial landfill development will be compatible with the overall facilities development schedules.

The schedule will include the following items:

- clearing and grubbing
- construction of permanent access roads and roadside drainage
- construction of the internal and perimeter drains, storm water management pond, and outlet
- initial excavation and site preparation
- construction of the perimeter berm
- construction of the underdrain
- construction of the leachate transmission system
- construction of any services such as hydro
- construction of the low solids pipeline.

Clearing and Grubbing

The following work will be undertaken and be reported on in the final report.

- Review of the existing site conditions, and assessment of the physical clearing needed.
- Assessment of the grubbing requirements.
- Estimation of the topsoil which can be stockpiled for final cover.

Clearing and grubbing will be necessary not only prior to landfilling, but also prior to construction of access roads, perimeter berms and ditches.

Construction of Internal and Perimeter Ditches, Storm Water Management Pond and Outlet

Construction of the internal and perimeter ditches will be one of the early construction activities in order to improve site drainage for the initial site development work and future construction. A perimeter drainage ditch with 3:1 side slopes and a 2 m depth was assumed for planning of the perimeter buffer zone. The final report will contain a drainage plan, typical sections for drainage features and the proposed surface slopes and ditch gradients.

The storm water management pond will be located at the south end of the landfill. This location was selected since it is the natural low area for drainage of most of the site and is adjacent to the proposed drainage outlet; therefore it will best utilize existing site gradients. The area of the pond will be approximately 40 000 m^2.

The function of the storm water management pond is to limit post-development 1:100 year flows to pre-development levels. The pond will therefore be dry except immediately following rainfall producing runoff and/or snowmelt events.

Preliminary engineering for the storm water management pond will incorporate site specific topography and climatic data to establish the pond dimensions, basic construction design parameters such as side slopes, materials, subgrade preparation and outlet requirements.

Construction of Permanent Roads and Roadside Drainage

This section of the final report will contain the following activities related to road construction.

- Specific construction activities such as subgrade preparation, granular material requirements.
- Scheduling requirement for specific construction activities.

Construction of Leachate Transmission Systems and Hydro Servicing

This section will identify those portions of the leachate transmission system which will be constructed initially, along with staging of the remainder of the system. Also, power supply requirements will be identified.

Preparation of Initial Area for Landfilling

The proposed location for the start of landfilling will be described based on the rationale provided in Section 4.4.1.

This description will include the following:

- Initial excavation.
- Berming around the excavation to prevent drainage into the excavation.
- Construction of ditches and the potentially contaminated water storage ponds.
- Construction and location of local temporary roads.
- Construction of a portion of the leachate collection system and the transmission system.

4.4.2 ONGOING LANDFILL OPERATIONS

Placement of Solidified Material

The deposition of solidified material in the landfill will proceed continuously throughout the year. On a typical day, landfilling will start with the delivery of trucked solidified material from the load-out area. This material will include any material accumulated from production of afternoon and night shifts. Trucks will drive from the load-out area along the permanent internal road adjacent to the Central Operating Area to the active landfill area, then branch off across a temporary road and down the ramp into the excavation to the active lift (refer to Figure 24, Page 113). The truck will end dump and then drive out up the ramp of the excavation, onto the internal road, and back to the load-out area. A bulldozer will then spread the solidified material on the active lift and a compactor will compact it.

If production of low solids material is scheduled, a bulldozer or loader will shape berms out of the high solids solidified material. The low solids material will be pumped through a pipeline into the bermed area.

Figure 24 (Page 113) shows a plan of the landfill under development.

Equipment used in the daily operation of the landfill will be a bulldozer, large vibratory compactor, rubber-tired or tracked loader, two haulage trucks for solidified material, a water truck, a fuel and maintenance truck and a pick-up truck.

Excavation

Excavation will be done by scraper(s) working on an excavation slope of about 6:1 (see Figure 26, Page 120). Excavation will take place as the scraper drives down the slope. The scraper will

turn at the bottom of the slope and climb back out of the excavation. The excavated material will be carried along the perimeter road to the area of final cover placement or to stockpiles for future covering or off-site transport.

Excavation operations will be limited to about six months of the year (typically May to October) because of difficulties due to wet or frozen ground conditions. Sufficient excavation must therefore take place in the summer months to allow for the interruption over the winter.

Export of Excess Clay Material

Excess clay will be transported off-site by truck. Clay from stockpiles will be loaded onto the trucks by front-end loader. The trucks will travel on the perimeter road and use one of the two access roads to Schram Road depending on the location of the stockpile.

Exports may keep pace with summer excavation or may, by stockpiling, be distributed more evenly throughout the year and throughout the landfill operating life.

Leachate Collection System

For ongoing operations, the leachate collection system will be advanced along with the landfill working face. There may be limitations on the construction season of the system depending on the underdrain design. The method of advancement of the underdrain will be resolved in the final report.

Final Cover Placement

When a portion of the upper lift of solidified material has been filled to grade, the final cover can be applied over the completed area. To achieve low hydrauylic conductivity, the clay must be

deposited under controlled conditions of moisture content, lift thickness and compaction. This operation cannot be undertaken in the winter because freezing of the clay impedes compaction. Therefore, cover placement will be limited to the summer months (typically May to October).

At the end of a covering season, a berm will be constructed at the limit of covering to keep surface drainage out of the excavation. The area of completed filling will grow over the winter period. This area will remain uncovered until covering operations can resume in the next season. Covering will resume inside the berm and progress throughout the summer. During this time, the completed area of filling will continue to grow. Covering operations will be managed so that by the end of the covering season, the completed area of filling has been totally covered except for a small setback of the cover from the edge of the completed lift. A new berm will be constructed at the limit of covering and the old berm removed.

Topsoil will be applied and revegetation of the completed cover undertaken as climatic conditions permit.

Surface Water Drainage

With the exception of the drainage features associated with the landfill cover, all drainage infrastructure will be in place as part of the initial development. As parts of the landfill are covered and graded, the ultimate drainage pattern for the landfill surface will emerge. Some temporary ditching will be required to maintain surface drainage until covering of the landfill is completed.

Collection and Monitoring of Potentially Contaminated Flows

All drainage from along the internal roads and the load-out area will be directed to potentially contaminated storage ponds

(Section 4.3.7). These ponds will be monitored regularly. If analysis shows the water to be contaminated, the ponds will be discharged to the physical/chemical treatment plant, via the leachate transmission system. If uncontaminated, the water can be discharged to the internal ditches draining to the storm water management pond.

Temporary Access Roads

Temporary access roads to the excavation ramp will be relocated as required to keep pace with the advancing working face. The roads will normally be moved at the end of the covering season to allow closing off of completed portions of the landfill.

The ramp into the excavation will be in two parts. The upper part, through the 5 m cover, will be constructed of clay and will be advanced along with the final cover. The lower part of the ramp, constructed of solidified material, will be advanced continuously with the completion of landfill lifts.

4.4.3 ENGINEERED LANDFILL CLOSURE PLAN

This section will describe the drainage design, long-term monitoring procedures and remedial works for the engineered landfill upon closure.

4.4.4 CONTINGENCY PLANNING

This section will address design and operations plans and procedures for upset conditions and such issues as operation of leachate system, emergency response procedures including, staffing and timing and flexibility of treatment.

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GLOSSARY OF TERMS

Active Operating Life:	Period of filling for the landfill.
Active Operation:	Energy inputs are required for landfill (leachate collection system) to function.
Contaminant:	Describes any foreign material released into the native environment.
Development Method:	Configuration of area in which landfill materials are deposited (e.g., area, cell, trench).
Engineered Devices:	Systems for leachate control (production or migration)
Facility Components:	The component facilities that make up the OWMC waste management system (i.e. landfill, incineration, physical/chemical treatment plant and solidification plant).
Landfill Concept:	The landfill type (e.g. conventional, shallow entombed, above-ground).
Landfill Features:	The major features forming part of the engineered landfill - landfill concept, engineered devices, mode of operation and development method.
Leachate:	Liquid released from the landfill.
Long Term:	Hundreds of years of time.
Mode of Operation:	Describes whether operation is active or passive. The mode of operation is related to the leachate collection system.
Passive Operation:	No outside energy source is required for landfill to function.
Solidified Mass:	Applies to the stable solidified material and incinerator slag after placement in the landfill.

GLOSSARY OF TERMS

(continued)

Solidified Material:	Materials after solidification.
Treated Residues:	Materials from physical/chemical treatment process before solidification.
Weathered Zone:	The surficial portion of the native soils which have been subjected to alteration by physical and/or chemical processes.

APPENDIX A

LITERATURE REVIEW OF SERVICE LIFE FOR ENGINEERING DEVICES

APPENDIX A
LITERATURE REVIEW OF
SERVICE LIFE FOR ENGINEERED DEVICES

1. INTRODUCTION

A postulate in the design of the OWMC engineered landfill is that ultimately the engineered devices (liner, cover and collection system) will fail. The service lives of these devices are estimated in the order of tens of years, whereas the landfill may produce leachate of concern over a period of hundreds of years. Therefore, emphasis has been placed on reliance on the natural environment to contain and isolate the solidified residues of the waste treatment processes.

A literature review was conducted to support the postulate of limited service lives for engineered devices. This memo documents a number of references on hazardous wastes landfill experience and engineered devices regarding design, failure, prevention and remediation of failure and service lives for devices. The conclusions identified within the text are based on information contained in the literature reviewed.

2. SUMMARY

Liners, covers and leachate collection systems may be made of many types of materials. Individual devices may be composed of synthetic materials, natural materials or combinations thereof. The life expectancy of synthetic materials (for use in any of the devices) is difficult to determine due to their relative newness. In the case of natural materials used in covers and liners (e.g. clay), little field investigation appears to have been done to confirm the degree of containment achieved and hence effective service life. While collection systems may have a relatively short life expectancy (suggested by an average life expectancy of 12 years for agricultural tile drains[3]), liners or covers may have a much greater life expectancy (50 to 150 years suggested by accelerated testing on synthetic membranes). The literature supports, then, that the life expectancy for devices is generally limited to figures in the order of tens of years.

The usable life of devices can be maximized by paying increased attention to design, construction, operation and maintenance to reduce the potential of failure. However, indefinite functioning of devices can probably be achieved only where remedial measures (repair or replacement) are possible.

3. LINER AND COVER SYSTEMS

3.1 General

The design of liner and cover systems can be quite different even though the general purpose of both is to contain the waste. In most designs the cover is intended to limit the infiltration of water into the waste whereas the liner is concerned with limiting the escape of leachate to the environment. The key element in these systems is a low hydraulic conductivity layer. The same kinds of materials have been used as low hydraulic conductivity layers in both liners and covers. Because many mechanisms of failure are common to both applications, liners and covers have been dealt with together in this literature review of service life expectancy for engineered devices.

A cover design may include several layers. Potential layers include (from top to bottom):

- vegetated top layer to stabilize the landform surface;
- drainage layer to prevent water build-up;
- upper protective layer;
- low hydraulic conductivity layer to limit the passage of water or gas;
- lower protective layer.

The protective layers are usually required only when the low hydraulic conductivity layer is a synthetic membrane. The drainage layer may double as the upper protective layer. In the case of the lower protective layer, a gas control function may also be incorporated.

Liner systems may be composed of many layers, some of which may be considered separately as leachate collection system components. Liner systems may include:

- leachate collection layer
- upper protective layer;
- primary liner;
- lower protective layer;

- primary liner leak detection layer;

- secondary liner.

The collection and detection layers may double as protective layers for liners made of synthetic membranes and provide a filtering function to prevent solids from entering the collection systems.

Many materials may be used as the low hydraulic conductivity layer. They may be grouped into synthetic membranes, clay or clay/soil mixtures, admix compositions, sprayed-on membranes and others. Typical materials in each group are:

Membranes:
- PVC - polyvinyl chloride
- CPE - chlorinated polyethylene
- CSPE - chlorosulfonated polyethylene ("Hypalon")
- LDPE - low density polyethylene
- HDPE - high density polyethylene
- IIR - butyl rubber
- EPDM/EPR - ethylene/propylene rubber
- CR - neoprene rubber

Clay:
- native clay
- bentonite/soil mixtures

Admix Compositions:
- paving asphalt concrete
- hydraulic asphalt concrete
- soil asphalt
- soil cement

Sprayed-on Membranes:
- catalytically blown asphalt sprayed on soil
- emulsified asphalt sprayed on soil or on fabric
- urethane modified asphalt
- liquid rubbers and plastics
- asphalt seals (for asphalt surfaces)

Others:
- prefabricated asphalt panels and sheetings
- soil sealants
- chemical absorptive liners (e.g. clays and minerals, acidic and basic fly ash, activated alumina, activated charcoal).

3.2 Failure Experience

Failure can be defined as the occurrence of liquid seepage or vapour diffusion beyond a critical value, deemed as an acceptable limit. Once failure occurs, the service life of a liner or cover is considered to have ended. Cover leakage is assessed by leachate production measured at the leachate collector. Liner leakage is assessed by the primary liner leak detector.

Establishing a service life for liners and covers is difficult because of limited experience. In the case of synthetic membranes, many polymers are too "young" for there to be reliable lifetime data. The oldest materials have been available for 50 years, but most of the polymers currently being used in liners have been around for 40 years or less.[5] While clays have historically been the material of choice for dams, surface impoundments and lagoons designed to restrain the movement of water, very little field information is available on the use of clay to impound organic materials or extreme pH fluids.[9] During the decades that clay has been used for impounding wastes, little attention has been paid to the degree of containment actually achieved.

Comprehensive studies of the use of clays[9] and synthetic materials[5] in hazardous waste containment and in other types of construction have identified the following mechanisms for failure:

SYNTHETIC LINERS AND COVERS

Failure Mechanisms		Liners	Covers
1.	Design - site (slopes)	X	X
	- system (inadequate protective layers)	X	X
	- membrane (wrong choice of material, thickness, quality)	X	X
2.	Manufacture - sheet (pinholes, weak areas, scrim)	X	X
	- factory seams	X	X
3.	Site Preparation - subgrade (compaction, texture, voids)	X	X
	- underdrains	X	
4.	Installation - exposure (wind, hail, animals, vandals, machinery)	X	X
	- field seams	X	X
	- structure seals (at liner penetrations)	X	X
5.	Non-Waste Factors		
	- weather (U.V., ozone, wind, abrasion, hail, temperature extremes, expansion/contraction, wet/dry, freeze/thaw)	X	X
	- biological (microbial attack)	X	X
	- physical aging (viscoelastic creep)	X	X
	- movement of subgrade, fill, slopes, (differential settlement, sloughing, block slip failure, earthquake)	X	X
	- operations (heavy machinery)	X	X
	- penetration (tree roots, burrowing animals, vandals)	X	X
6.	Waste Factors - chemical incompatibility	X	X
	- environmental stress cracking	X	X
	- chemical aging (polymer degradation)	X	X
	- gas production		X

CLAY LINERS AND COVERS

Failure Mechanisms	Liners	Covers
1. Design - site (slopes)	X	X
- system (inadequate protective layers, filter layers)	X	X
- clay (mineral choice, heterogeneity)	X	X
2. Site Preparation - subgrade compaction	X	X
3. Installation - exposure (wet/dry, freeze/thaw, erosion)	X	X
- incomplete mixing or inadequate mixing rate of admixtures (e.g. bentonite)	X	X
- placement specifications (compaction, water content, lift thickness)	X	X
4. Non-Waste Factors		
- settlement (subsidence, differential settlement)	X	X
- piping (internal erosion)	X	X
- desiccation (thermal, plant withdrawal)	X	X
- penetration (tree roots, burrowing animals, vandals)	X	X
- erosion	X	X
- earthquakes	X	X
5. Waste Factors		
- chemical incompatibility (chemical desiccation)	X	X
- gas production		X

ADMIX COMPOSITIONS AND SPRAYED-ON MEMBRANES

Other Specific Failure Mechanisms

1. Installation - pinholes (sprayed-on membranes)
   - continuity, uniformity (sprayed-on membranes)

2. Non-Waste Factors - shrink cracking (soil cement)
   - heat creep and tearing (asphalt concrete)
   - sun aging (asphalt concrete, asphalt panels)
   - low temperature embrittlement (asphalt concrete, soil cement, soil sealants)
   - freeze/thaw cracking (asphalt concrete, soil cement, soil sealants)
   - plant penetration (asphalt concrete, soil sealants, admix compositions and sprayed-on membranes)

3. Waste Factors
   - hydrocarbon solvents, fats, oils (asphalt concrete)
   - acidic/alkaline conditions, sulfates (concrete)
   - acidic conditions, organics, sulfuric wastes (soil cement)
   - salts, multivalent cations (sprayed-on membranes)

Note: Design, manufacture and site preparation are similar to that previously identified for other types of liners and covers.

It should be emphasized that some of the identified failure mechanisms may not be applicable for the OWMC engineered landfill due to the treated and solidified nature of the material being landfilled and the landfill concept (shallow entombed). These include:

- weather (prevented by burial);
- biological (virtually no biodegradation expected);
- erosion (largely prevented by absence of surface relief);
- settlement/differential settlement of waste (low voids, stable homogeneous waste expected);
- penetration by tree roots, burrowing animals, vandals (prevented by 5 m thick cover);
- gas production (not anticipated from waste).

3.3 Prevention

Prevention of liner and cover failure can be achieved in a number of areas, such as:

a) design and construction;

b) operation and maintenance.

Where potential failure mechanisms can be anticipated, designs may incorporate features to prevent or limit their occurrence. These include the proper choice of materials for system components, thicknesses of component layers, slopes, and incorporation of protective and filter layers. For example, a cover might be designed to respond well to differential settlement, maintenance of vegetation, gas production, freeze/thaw cycling and erosion, plus allow for easy repair.

A secondary liner with a collection system is advised in two references to monitor the performance of the primary liner and to serve as a back-up system.[5,8] Note that this advice pertains to untreated hazardous waste and may not be applicable in OWMC's case where the waste will be treated and solidified. Another author suggests a leak detection system below the secondary liner where presence of contamination would indicate total liner system failure and serve as the cue to exhume the waste.[7]

Construction must be carried out in accordance with the design. Care must be taken to preserve liner and cover integrity during construction (e.g., prevent drying of clay) and to prevent damage. The time of year, weather conditions and even time of day for construction may be restricted.(8)

As with construction, care must be exercised during filling operations to avoid damage to liner and cover systems. Regular inspection and repair of damage as it occurs and while it is easily corrected is important. Early detection minimizes adverse impacts and the difficulty and expense of repair. Maintenance of covers would include filling of low spots to prevent ponding, restoration of eroded areas and maintenance of proper surface vegetation.

3.4 Remedies

Several remedial actions are available to control cover failures. Localized membrane repair may be attempted if the point of failure can be identified. For clay covers, surface sealing and recapping can be achieved through recompaction for minor problems. More serious failures may require installing a new or thicker clay cover or synthetic membrane cover. Cover repairs are most effective when combined with grading and revegetation. Surface water diversion and collection structures may be required to prevent further erosion.

The failure of a liner may result in leachate migration and ground water contamination. To minimize the adverse impact, leachate production may be reduced by reducing infiltration through the cover by methods described above. More extensive remedial actions would be the use of cut-off walls, purge wells with ground water treatment or lowering the water table by pumping to prevent contact with the waste. Liner repair is usually very difficult and expensive.

Other remedial actions are possible although some are unproven and costly in comparison to limiting infiltration. These include in-situ treatment of ground water and bottom sealing (solidifying the interface of the waste and the water table with resins).(9)

Another option is to exhume the waste and contaminated soil for treatment. Stabilization or fixation of the waste materials is identified as a means to reduce or eliminate the leaching potential of the waste.

For the OWMC Facility design, the waste materials will be treated and solidified prior to placement in the landfill, thereby reducing the leaching potential.

3.5 Conclusions Identified in Literature Search

1. The service lifetime of flexible membranes is difficult to predict due to the limited experience industry has had with these particularly when used in hazardous waste and leachate containment.(5)

2. Flexible membranes must be considered to have finite service lifetimes. There is no basis for believing they will be servicable "forever", but under some conditions they could last for considerable lengths of time.(5)

3. When properly selected, installed and used, a flexible membrane may remain serviceable for at least 25 years. This is based on experience with membranes in non-waste environments taking into account recent advances in knowledge of membrane selection and installation. A 25 year service life thus appears to be a conservative minimum.(5)

4. Longer periods of membrane serviceability, perhaps 50 to 150 years or more may be projected on the basis of laboratory accelerated tests. However these long-term projections cannot be validated because the polymer used in making the membranes have been commercially available for less than 50 years.(5)

5. There are many factors that can affect the service life of a membrane. Maximum membrane lifetime will only be achieved if all appropriate steps have been taken in the design, selection and installation of the material.(5)

6. The probability of failure of properly designed and constructed clay liners and covers is difficult to predict because of limited experience and monitoring results.(9)

7. Design, construction and testing techniques can minimize the probability of clay liner or cover failure.(9)

4. LEACHATE COLLECTION SYSTEMS

4.1 General

Leachate collection systems incorporate some or all of the following components:

- drainage layer
- drain pipe
- filter layer
- collection sump

Typically the drainage layer is constructed of granular materials and is underlain by a low hydraulic conductivity layer (soil or synthetic membrane). Filter layers may be included on either side of the drainage layer depending on the adjacent materials (waste and low hydraulic conductivity layers). Pipes may be incorporated to help conduct drainage to the sump or wet well from which the leachate is withdrawn.

Relatively new on the market are "drainage nets" made of synthetic materials (e.g., high density polyethylene, polypropylene) designed to be used in conjunction with synthetic membranes and geotextiles. Flow is conducted along the thin net. The proper functioning of the net depends on its channels remaining open and unclogged by soil (or waste) particles. A promising application for drainage nets is in leak detectors where direct contact with the waste or soils is not expected, low flow capacity is anticipated and thinness is an advantage (less landfill capacity sacrificed). The drainage net would be sandwiched between two low hydraulic conductivity layers, usually synthetic membranes.

4.2 Failure Experience

In the related field of agricultural drainage systems, experience indicates that the service of drains is short, with repairs expected to be required after about 12 years of service. A study of 103 agricultural tile drains in Ohio showed that all drains over 40 years of age had required maintenance. Problems mostly developed at drain junctions and physical factors tended to predominate.

Experience in leachate collection systems is limited. Most systems have been in general use five years or less. A survey of over 20 landfill operations identified six incidents of problems:

- biological clogging of a drain envelope (drainage material) due to poor design;
- clogging of a standpipe with solids due to design and construction errors (no filter layer was installed);
- siltation of drain pipe;
- undefined drainage problems;
- cementation of the drain envelope.

In the U.S., the Resource Conservation and Recovery Act (RCRA) stipulates that the depth of leachate over the liner must not exceed 30 cm (1 foot). The inability of a leachate collection system to meet this criterion constitutes failure.

The mechanisms of failure have been identified in these main groups:

i) physical mechanisms
ii) chemical mechanisms
iii) biochemical mechanisms
iv) biological mechanisms

Physical Mechanisms

This is the most common cause and most understood cause of drain failure. Physical failure can be due to:

- inadequate capacity
- structural failure
- sedimentation

Inadequate pipe carrying capacity can be caused by:

a) underestimation of the maximum design flow;

b) problems in the outlet;

c) inadequate pipe spacing, diameter or slope;

d) insufficient slot area.

Inadequate flow capacity in the drainage layer or envelope can also result in clogging.

Structural failures can be caused by mechanical crushing or displacement. Mechanical causes are due to operational and event factor types (e.g. differential settlement). Compaction of wastes and general loading during normal operations can cause crushing or displacement of the pipe. Physical deterioration can also be caused chemically, such as by solvents.

Sedimentation, or trapping of solids in the collection system can be caused by a number of design problems and events. Sedimentation in the pipe requires both a source of solids and a mechanism by which they can settle out. Sedimentary material appears in leachate as suspended solids arising from the waste, daily cover, cap, envelope or filter materials.

Chemical Mechanisms

Chemical mechanisms for clogging invoive the formation of insoluble precipitates which deposit on the insides of drain-pipes, linings and drain envelopes. The most common build-up is calcium carbonate, however, manganese carbonate and other insoluble forms (sulfides and silicates) have been found in clogged or partially encrusted drainage systems.

One reaction leading to calcium carbonate encrustation is the formation of relatively insoluble calcium carbonate ($CaCO_3$) from calcium bicarbonate ($Ca(HCO_3)_2$) solutions when pressure reduction allows carbon dioxide to escape.

Another means of calcium carbonate deposition in pipes or in the drainage envelopes is when residual leachate caught in the system evaporates during dry periods.

Biochemical Mechanisms

The principal products resulting from biochemical mechanisms are iron compounds which deposit and build-up on the pipe surfaces and in the envelope material. The deposits generally contain organic materials as well in the form of adherent, sometimes filamentous slimes and organic complexes.

For example, one mixed type of precipitate $Fe(OH)3$ with biological slime (called ochre in much of the literature) is particularly adherent and can very rapidly block up interstices in the drain envelope, entrance slots or even the insides of the pipe.

The solidified mass from the OWMC treatment facility will be largely inorganic; therefore, there will be little support for bacterial growth. This will reduce the potential for this mechanism for clogging.

Biological Mechanisms

Biological clogging is produced when organism growth fills the pipe or interstices of the drain envelope and interferes with normal flow of leachate. For growth to occur, bacteria must have a supportive environment. The very low levels of organic chemicals as a bacterial food in the solidified mass from the OWMC Facility will reduce the growth of bacteria and the potential for this clogging mechanism.

4.3 Prevention

Prevention of clogging can be achieved in a number of areas including:

a) design and construction

b) operation and maintenance

c) control of waste disposal

d) direct treatment.

Proper design and then construction according to design is the most effective preventive measure. The design should specifically aim to prevent or minimize the potential for clogging. This includes proper sizing of components (e.g., pump size, pipe size, spacing and slope), material selection for strength and compatibility with landfilled material and leachate, and special features included to prevent or remedy clogging (e.g., cleanouts, graded or layered filter, submerged outlet).

Operation and maintenance is also of considerable importance in preventing clogging. Operational considerations include taking special care during placement and compaction of material and during other operations while in the vicinity of a drain. Maintenance considerations include monitoring and inspection of the collection system and regular preventive cleaning.

Control of waste disposal may consist of minimizing nutrient-rich waste (not present in the OWMC landfill) and adding biocides to decrease bacteria growth and control biochemical and biological precipitation. Maintaining a low pH can minimize bacterial activity as well as reduce calcium carbonate precipitation, but may contribute to deterioration of collection system materials. Solvents, oxidizing agents and caustic or corrosive chemicals which can cause collection system deterioration should not be a concern given the nature of the OWMC solidified material.

Direct treatment may involve the periodic application of biocides to kill bacteria or acid to dissolve deposits in their early stages of development. This can be used in conjunction with pipe cleaning and other preventive measures to inhibit clogging the pipe and to remove accumulations before clogging becomes a problem.

Remedies

Remedial measures are intended to eliminate the clogging problem once it has occurred. Remedial measures include:

a) excavation and replacement;

b) physical methods:

c) chemical methods.

Excavation and replacement is the most difficult and expensive remedial measure. With the exception of the perimeter drain, replacement of a leachate collector at the OWMC Facility would require exhuming the overlying solidified mass.

Physical methods for unclogging pipes include mechanical devices and hydraulic cleaning (low and high pressure jets).

Chemical methods use acid to dissolve clogs in pipes. They are less effective for treating clogged drainage envelopes and may be dangerous to the operator.

Conclusions Identified in Literature Search

1. It is reasonable to expect clogging in leachate collection systems to occur during the active and post-closure lifetime of waste landfills.(2)

2. Established preventive and remedial techniques to avoid or mitigate clogging can generally be used at hazardous waste sites.(2)

3. Preventive methods are far superior to remedial techniques. Repair or replacement can be expensive and potentially dangerous.(2) For example, acid treatment to dissolve deposits in collection pipes may not be appropriate due to their effect on the cement based solidified mass.

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APPENDIX B

COMPARATIVE EVALUATION OF LANDFILL CONCEPTS

APPENDIX B

TABLE B-1

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF LANDFILL CONCEPTS

CRITERIA	SUB-CRITERIA	SYSTEM	RATING[1]	RATIONALE
Performance	Disruption of natural surface water and ground water systems	Above-ground and Conventional	High	In all cases, the water table is expected to rise up to near the surface of the landfill forming a ground water mound. As a result there would be surficial leachate breakout ("bathtub effect") and increased downflow of leachate (relative to the natural ground water downflow at the site) for both the above-ground and conventional concept (GLAL[4], 1987).
	Disruption of natural surface water and ground water systems	Shallow entombed	Low*	The leachate downflow from the shallow entombed concept is comparable to the natural rate of ground water downflow at the site. In addition, the modelling conducted by Gartner Lee Associates indicated only a fraction of the surficial outflow for the shallow entombed concept, which will be a large extent uncontaminated since it flows only through the cover system (which can only be contaminated by upward diffusion, a very slow process) (GLAL[4], 1987).
Performance	Impact on ground water flow	Above-ground	High	This concept mounds leachate higher than conventional because of the above ground configuration and therefore has a high hydraulic gradient to force leachate into aquifer pathway.
	Impact on ground water flow	Conventional	Intermediate	This concept produces a ground water mound above the existing water table, but not as high as above ground. Therefore it is rated as intermediate.

1. *Indicates best rating for sub-criterion.

TABLE B-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF LANDFILL CONCEPTS

CRITERIA	SUB-CRITERIA	SYSTEM	RATING[1]	RATIONALE
	Impact on ground water flow	Shallow entombed	Low*	The shallow entombed concept does not increase the hydraulic gradient over existing conditions and therefore is rated low.
Performance	Contaminant transport time to underlying aquifer	All	Long	Both generic and site-adapted contaminant transport modelling conducted by Gartner Lee Associates showed that transport time to the underlying aquifer at Site LF-9C would be long for all three concepts, in the order of 800 to 1200 years. This is related directly to the depth and uniformity of the confining layer at LF-9C (GLAL[4], 1987).
Performance	Potential for off-site contamination resulting from lateral weathered zone flow	Above-ground and Conventional	High	The above-ground and conventional concepts provide protection from lateral contaminant transport through the weathered zone by means of engineered devices such as liners and/or collection systems. Assuming that these devices fail (see Section 2.6), leachate would be in direct contact with the weathered zone (GLAL[4], 1987).
	Potential for off-site contamination resulting from lateral weathered zone flow	Shallow entombed	Low*	The shallow entombed concept places all waste below the weathered zone, so that the weathered zone would only be contaminated by upward flow (not expected) or by upward diffusion (very slow) (GLAL[4], 1987).

1. *Indicates best rating for sub-criterion.

TABLE B-1 (continued)
RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF LANDFILL CONCEPTS

CRITERIA	SUB-CRITERIA	SYSTEM	RATING[1]	RATIONALE
Performance	Potential for direct surface water contamination	Above-ground and Conventional	High	Direct surficial leachate discharges could result for the above-ground or conventional concepts due to the ground water mound above ground surface (GLAL[4], 1987).
	Potential for direct surface water contamination	Shallow entombed	Low*	The direct surficial leachate discharge would be substantially reduced for the shallow entombed concept. They would depend on the rate of upward flow and diffusion into the cover system which are low relative to direct leachate flow from the other concepts (GLAL[4], 1987).
Performance	Efficiency of land use	Above-ground	Low	11 to 57 years of landfill life depending on assumptions used for landfill development (see Table 2 on Page 43 of text).
	Efficiency of land use	Conventional	High*	14 to 83 years of landfill life.
	Efficiency of land use	Shallow entombed	Low	9 to 68 years of landfill life.
Performance	Leachate produced	Above-ground and Conventional	High	Leachate is produced at a rate equal to the ability of incident precipitation to infiltrate the cover and enter the waste. Additional leachate beyond field capacity will exit the landfill as surface springs.

1. *Indicates best rating for sub-criterion.

TABLE B-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF LANDFILL CONCEPTS

CRITERIA	SUB-CRITERIA	SYSTEM	RATING[1]	RATIONALE
	Leachate produced	Shallow entombed	Low*	After equilibrium conditions, leachate production is limited not by infiltration through the cover but by the hydraulic conductivity of the natural hydrogeologic setting.
Performance	Proven technology	All	-	In order to determine with certainty the impact of a technology on the environment, it is necessary to use a reliable and extensive data base in predicting performance and reliability. This is not available.
Performance	Long-term maintenance requirements	Above-ground	High	This concept relies on devices for control of leachate migration. Therefore to maximize the life of these devices, active maintenance is required.
	Long-term maintenance requirements	Conventional	Intermediate	This concept relies partially on devices for control of leachate migration to the surface water or weathered zone pathways. Therefore active maintenance of these devices is required.

1. *Indicates best rating for sub-criterion.

TABLE B-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF LANDFILL CONCEPTS

CRITERIA	SUB-CRITERIA	SYSTEM	RATING[1]	RATIONALE
	Long-term maintenance requirements	Shallow entombed	Low*	The only device required is a simple cover which should require only minor maintenance.
Flexibility	Design flexibility concepts	Above-ground	Low	No practical design flexibility.
	Design flexibility concepts	Conventional	Low	No practical design flexibility.
	Design flexibility concepts	Shallow entombed	Intermediate*	The shallow entombed concept could be converted to a conventional concept after completion by removing the cover system and constructing the above-ground portion. This decision can be based on long-term monitoring of leachate quantity and quality.
Flexibility	Design flexibility devices	Above-ground	Low	Minimum requirements are a liner and underdrains for above-ground landfill.
	Design flexibility devices	Conventional	Intermediate	Minimum requirement is a perimeter drain.
	Design flexibility devices	Shallow entombed	High*	Flexibility for all devices. Liner and leachate collection system not required and simple or complex cover are feasible.

1. *Indicates best rating for sub-criterion.

TABLE B-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF LANDFILL CONCEPTS

CRITERIA	SUB-CRITERIA	SYSTEM	RATING[1]	RATIONALE
Design Flexibility	Operations	Above-ground	Low	The above-ground landfill concept, by definition, must be operated in an active mode (i.e. continuous collection and treatment of any leachate produced). This is incongruous with the assumption of a passive operational mode equivalent to an engineered systems failure and could only be a viable concept if OWMC were to commit to the maintenance of the engineered systems indefinitely (GLAL[4], 1987).
	Operations	Conventional	Intermediate	Generic ground water and contaminant transport modelling conducted by Gartner Lee Associates has demonstrated that the conventional landfill concept would probably be unacceptable in the passive operational mode. However, it is possible that a simple leachate collection system consisting of perimeter toe drains would provide an adequate active operational system (GLAL[4], 1987).
	Operations	Shallow entombed	High*	The shallow entombed concept could be operated successfully in either the passive or active operational modes, based on preliminary generic modelling results conducted by Gartner Lee Associates. This gives it a greater degree of operational flexibility than the other two concepts (GLAL[4], 1987).

1. *Indicates best rating for sub-criterion.

TABLE B-1 (continued)
RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF LANDFILL CONCEPTS

CRITERIA	SUB-CRITERIA	SYSTEM	RATING[1]	RATIONALE
Flexibility	Sensitivity to changes in feed rate	All	Intermediate	No distinction among the three concepts is expected with respect to sensitivity to changes in feed rate.
Flexibility	Sensitivity to changes in feed composition	Above-ground and Conventional	Intermediate	Affects forming for disposal of low solids solidified material in the above ground portions of these concept either using high solids material or formwork.
	Sensitivity to changes in feed composition	Shallow entombed	Low*	Shallow entombed is a completely below-ground operation and therefore forming requirements for low solids solidified material is not a major concern.
Flexibility	Site after use potential	Above-ground and Conventional	Low	Above-ground and conventional have greater effect on topography than shallow entombed.

1. *Indicates best rating for sub-criterion.

TABLE B-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF LANDFILL CONCEPTS

CRITERIA	SUB-CRITERIA	SYSTEM	RATING[1]	RATIONALE
	Site after use potential	Shallow entombed	Intermediate	Shallow entombed results in minimal long-term changes to topography.
Reliability	Regular maintenance requirements (during operations)	Above-ground	High	Above-ground landfill requires an active leachate collection system requiring continuous maintenance and large above-ground slopes to protect.
	Regular maintenance requirements (during operations)	Conventional	High	Conventional landfill will require, at a minimum, maintenance of perimeter drains and above-ground slope protection.
	Regular maintenance requirements (during operations)	Shallow entombed	Low*	Shallow entombed landfill can have passively operated leachate collection system and no above-ground slopes to protect.

1. *Indicates best rating for sub-criterion.

TABLE B-1 (continued)
RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF LANDFILL CONCEPTS

CRITERIA	SUB-CRITERIA	SYSTEM	RATING[1]	RATIONALE
Reliability	Spares - Requirement/Availability	Above-ground	High	General All concepts have high availability of spares. Active leachate colection system requires highest spares.
	Spares - Requirement/Availability	Conventional	Intermediate	Maintenance of perimeter drains (minimum requirement) will require intermediate number of spares relative to other concepts.
	Spares - Requirement/Availability	Shallow entombed	Low*	If operated in passive mode of operation, no spares required.
Reliability	Robustness	Above-ground	High	This concept utilizes highly engineered devices, which generally are not repairable.
	Robustness	Conventional	Intermediate	This concept utilizes a perimeter drain for leachate control which will fail in time but is repairable or replaceable.

1. *Indicates best rating for sub-criterion.

TABLE B-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF LANDFILL CONCEPTS

CRITERIA	SUB-CRITERIA	SYSTEM	RATING[1]	RATIONALE
	Robustness	Shallow entombed	Low*	Shallow entombed is completely in-ground and may not be dependent on synthetic or engineered devices.
Reliability	Vulnerability to interruption of operations	All	Low	Short-term disruption of operation of control devices should not produce any significant effect.
Safety	Occupational risk during normal or upset conditions	All	Low	Due to the nature of the material being disposed of occupational risk is considered low and is not altered by the concept used.
Operations	Complexity of process	Above-ground	High	The engineered devices are complex in nature and therefore this concept is rated high.
	Complexity of process	Conventional	Intermediate	Although some devices are used in this concept, there are not as many used as for above-ground and it is relatively more simple. Therefore, an intermediate rating is applied.
	Complexity of process	Shallow entombed	Low*	Since no devices are utitlized in this concept the complexity at the process is rate low.

1. Indicates best rating for sub-criterion.

TABLE B-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF LANDFILL CONCEPTS

CRITERIA	SUB-CRITERIA	SYSTEM	RATING[1]	RATIONALE
Operations	Off-Site Effects Dust/Noise/Visual			Work program is not yet complete.
Operations	Off-Site Effects Clay Material Import/Export	Above-ground	Low*	For above-ground landfill there is no excavation, therefore, materials must be imported. A range of 22,000 to 74,000 m^3 must be imported depending on the operation assumptions. This represents 7 to 22 daily truck trips (one-way).
	Off-Site Effects Clay Material Import/Export	Conventional	Intermediate	The conventional landfill concept generates more excavated clay on-site than is required for final cover or berm construction. This clay must be disposed of either on-site or off-site. 109,000 to 307,000 m^3 of excess material must be disposed of. This represents 32 to 88 daily truck trips (one-way).

1. Indicates best rating for sub-criterion.

TABLE B-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF LANDFILL CONCEPTS

CRITERIA	SUB-CRITERIA	SYSTEM	RATING[1]	RATIONALE
Operations	Off-Site Effects Clay Material Import/Export	Shallow entombed	High	Excess material is also produced for shallow entombed. 147 000 to 379 000 m^3 must be disposed of depending on the operation assumptions. This represents 43 to 109 daily truck trips (one-way).
Operations	Ease of Monitoring - Performance/Environmental	All	Intermediate	No distinctions among the three concepts is expected with respect to ease of monitoring. Work program is not yet complete.

1. Indicates best rating for sub-criterion.

TABLE B-1 (continued)
RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF LANDFILL CONCEPTS

CRITERIA	SUB-CRITERIA	SYSTEM	RATING[1]	RATIONALE	
				Total Solidification	Partial Solidification
Commercial and Economic[2]	Capital	Above-ground	High	$ 4,600,000	$3,310,000
	Capital	Conventional	Low*	$ 3,191,000	$2,570,000
	Capital	Shallow entombed	Intermediate	$ 4,225,000	$2,867,000
Cost	Operations Costs Year 10	Above-ground	High	$ 5,245,000	$ 2,923,000
	Operations Costs Year 10	Conventional	Low*	$ 3,793,000	$ 2,019,000
	Operations Costs Year 10	Shallow entombed	Intermediate	$ 4,644,000	$ 2,496,000

1. *Indicates best rating for sub-criterion.
2. Includes land acquisition costs added to balance cost figures based on common landfill life.

TABLE B-1 (continued)
RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF LANDFILL CONCEPTS

CRITERIA	SUB-CRITERIA	SYSTEM	RATING[1]	RATIONALE
Commercial and Economic	Closure/Post-Closure	Above-ground	High	The devices used in this concept for leachate control must be operated and maintained through this period and therefore the costs are high
		Conventional	Intermediate	The devices used in this concept for leachate control must be operated and maintained through this period however, they are simple systems and therefore the costs are intermediate.
		Shallow entombed	Low*	No devices are used in this option, therefore maintenance activities are minimal.

1. *Indicates best rating for sub-criterion.

APPENDIX C

EXCESS CLAY MATERIAL DISPOSAL/IMPORT

APPENDIX C
EXCESS CLAY MATERIAL DISPOSAL/IMPORT

INTRODUCTION

Phase 4A of the Facility site selection process was undertaken using the assumption that no clay material would be either imported or exported from the site. This assumption may have to be revised based on further development work.

This report summarizes the results of the Landfill Working Group's task of reviewing the requirments for either trucking excess clay material off-site, for conventional and shallow entombed concepts, or importing clay from off-site for the above-ground concept.

Section 1 provides the details of the excess clay material produced for conventional and shallow entombed concepts and the import requirements for the above-ground concept for the three development methods (i.e., cell, trench and area). Section 3 indicates that for the shallow entombed concept, at least, the excess clay material should not be disposed of on-site. Therefore, clay material will have to be disposed of off-site or imported for all landfill concepts. The magnitude of the transport of clay material is affected by the concept considered and the development method.

Section 2 identifies off-site locations that may be available for either disposal or import of material. The pits and quarries considered for disposal will have to be investigated in Phase 4B to identify interest, capacity and regulatory requirements. The same issues will have to be considered for source locations identified.

Section 4 provides a preliminary review of the truck fleet requirements for transport of clay. Annual operating costs, for the landfill concepts are also developed for average haul distances to the locations identified in Section 2. These will have to be developed in more detail in conjunction with the work in Section 2. Based on this general level of investigation, there may be significant impacts off-site, based on the number of trucks required for transport of this clay material. These impacts should be considered as part of the Phase 4B work program.

1. QUANTITIES OF CLAY REQUIRED FOR IMPORT TO OR EXPORT FROM THE FACILITY

Both the shallow entombed landfill concept and the conventional landfill concept generate more excavated clay on site than is necessary for final cover or berm construction. This excess clay must be disposed of either on-site or off-site. The opposite occurs with the above-ground landfill concept where, because there is no excavation, much of the material for final cover and berms must be imported.

The net clay requirement for the perimeter berm, after considering the contribution of clay from perimeter ditch excavation, was estimated to be 297 000 m^3. This quantity was subtracted from the excess clay from the shallow entombed and conventional landfill concepts and added to the cover requirements of the above-ground landfill concept. The results are summarized in Table 1 for each landfill concept and development method (cell, trench and area).

There is a possibility that some portion of the excess clay may be disposed of on-site by distribution over the area of completed landfilling. The depth of filling, for the shallow entombed landfill concept, can be calculated by dividing excess clay quantity by the area. The available area is approximately 635 000 m^2 resulting in 8.2 metres depth of fill for the area method.

The annual production of excess material and the annual requirements for imported material were calculated and are provided in Tables 2, 3 and 4.

TABLE 1
TOTAL QUANTITIES OF CLAY MATERIALS*

a) Shallow Entombed (Excess Material)

cell-total solidification	- 2 303 000 m^3
cell-partial solidification	- 1 913 000 m^3
trench	- 2 792 000 m^3
area	- 5 194 000 m^3

b) Conventional (Excess Material)

cell-total solidification	- 3 014 000 m^3
cell-partial solidification	- 2 699 000 m^3
trench	- 3 789 000 m^3
area	- 5 325 000 m^3

NOTE: Berm quantity requirement of 297 000 m^3 has been deducted from above figures. All quantities based on 2:1 in-ground side slopes.

c) Above-Ground (Import Material)

cell-total solidification	- 812 000 m^3
cell-partial solidification	- 769 000 m^3
trench	- 842 000 m^3
area	- 915 000 m^3

NOTE: 1. Berm quantity requirement of 297 000 m^3 has been added to the above figures.

2. Quantities are based on a 15% bulking factor.

*Quantities rounded to nearest 1000 m^3.

TABLE 2

ANNUAL EXCESS CLAY MATERIAL QUANTITIES*
SHALLOW ENTOMBED LANDFILL

YEAR	TOTAL SOLIDIFICATION			PARTIAL SOLIDIFICATION		
	Cell (m^3)	Trench (m^3)	Area (m^3)	Cell (m^3)	Trench (m^3)	Area (m^3)
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	107 000	107 000	130 000	0	0	0
5	172 000	172 000	181 000	0	0	0
6	206 000	206 000	217 000	46 000	42 000	61 000
7	240 000	240 000	254 000	106 000	104 000	110 000
8	275 000	275 000	290 000	121 000	119 000	126 000
9	309 000	309 000	326 000	135 000	134 000	142 000
10	343 000	343 000	363 000	149 000	147 000	156 000
11	345 000	345 000	364 000	149 000	147 000	156 000
12	347 000	347 000	366 000	149 000	148 000	156 000
13		348 000	368 000	149 000	148 000	156 000
14			370 000	150 000	148 000	156 000
15			372 000	150 000	148 000	157 000
16			374 000	150 000	148 000	157 000
17			375 000	150 000	149 000	157 000
18			377 000	150 000	149 000	157 000
19			379 000	151 000	149 000	157 000
20					149 000	158 000
21					149 000	158 000
22					149 000	158 000
23					150 000	158 000
24					150 000	158 000
25					150 000	158 000
26						159 000
27						159 000
28						159 000
29						159 000
30						159 000
31						160 000
32						160 000
33						160 000
34						160 000
35						161 000
36						161 000
37						161 000
38						161 000
39						161 000
TOTAL**	2 344 000	2 692 000	5 106 000	1 905 000	2 777 000	5 192 000

* Quantities rounded to nearest 1000 m^3.
** Totals are for an even number of years of operation; therefore, do not agree exactly with the value on Table 6.

NOTE: Quantities include a 15% bulking factor.

TABLE 3

ANNUAL EXCESS CLAY MATERIAL QUANTITIES*

CONVENTIONAL LANDFILL

YEAR	TOTAL SOLIDIFICATION			PARTIAL SOLIDIFICATION		
	Cell (m^3)	Trench (m^3)	Area (m^3)	Cell (m^3)	Trench (m^3)	Area (m^3)
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	6 000	7 000	42 000	0	0	0
5	129 000	129 000	144 000	0	0	0
6	154 000	155 000	173 000	0	0	0
7	180 000	181 000	202 000	32 000	37 000	76 000
8	206 000	206 000	230 000	89 000	90 000	100 000
9	231 000	232 000	259 000	100 000	101 000	113 000
10	257 000	258 000	288 000	109 000	111 000	124 000
11	258 000	259 000	289 000	110 000	111 000	124 000
12	260 000	261 000	291 000	110 000	111 000	124 000
13	261 000	262 000	293 000	110 000	111 000	124 000
14	262 000	263 000	294 000	110 000	111 000	124 000
15	264 000	265 000	295 000	110 000	112 000	125 000
16	265 000	266 000	297 000	110 000	112 000	125 000
17	266 000	267 000	298 000	110 000	112 000	125 000
18		268 000	300 000	111 000	112 000	125 000
19		270 000	301 000	111 000	112 000	125 000
20		271 000	303 000	111 000	112 000	125 000
21			304 000	111 000	112 000	125 000
22			306 000	111 000	112 000	126 000
23			307 000	111 000	112 000	126 000
24				111 000	113 000	126 000
25				111 000	113 000	126 000
26				112 000	113 000	126 000
27				112 000	113 000	126 000
28				112 000	113 000	126 000
29				112 000	113 000	126 000
30				112 000	113 000	127 000
31				112 000	114 000	127 000
32					114 000	127 000
33					114 000	127 000
34					114 000	128 000
35					114 000	128 000
36					115 000	128 000
37					115 000	128 000
38					115 000	128 000
39					115 000	128 000
40					115 000	129 000
41						129 000
42						129 000
43						129 000
44						129 000
45						129 000
46						129 000
47						129 000
48						129 000
TOTAL**	2 999 000	3 820 000	5 216 000	2 666 000	3 727 000	5 229 000

* Quantities rounded to nearest 1 000m^3.

** Totals are for an even number of years operation; therefore, do not agree exactly with the value on Table 6.

TABLE 4

ANNUAL IMPORT CLAY MATERIAL QUANTITIES*
ABOVE-GROUND LANDFILL

YEAR	TOTAL SOLIDIFICATION			PARTIAL SOLIDIFICATION		
	Cell (m^3)	Trench (m^3)	Area (m^3)	Cell (m^3)	Trench (m^3)	Area (m^3)
1**	161 000	160 000	157 000	155 000	153 000	152 000
2**	165 000	164 000	160 000	157 000	155 000	154 000
3	26 000	24 000	18 000	13 000	10 000	8 000
4	32 000	29 000	22 000	16 000	13 000	9 000
5	37 000	34 000	25 000	19 000	15 000	11 000
6	44 000	41 000	30 000	23 000	18 000	13 000
7	51 000	48 000	36 000	27 000	21 000	15 000
8	59 000	55 000	41 000	31 000	24 000	18 000
9	66 000	61 000	46 000	34 000	27 000	20 000
10	73 000	68 000	51 000	38 000	29 000	22 000
11	74 000	68 000	51 000	38 000	29 000	22 000
12		69 000	51 000	38 000	29 000	22 000
13			52 000	38 000	29 000	22 000
14			52 000	38 000	29 000	22 000
15			52 000	38 000	29 000	22 000
16			52 000	38 000	29 000	22 000
17				38 000	30 000	22 000
18					30 000	22 000
19					30 000	22 000
20					30 000	22 000
21					30 000	22 000
22					30 000	22 000
23					30 000	22 000
24						22 000
25						22 000
26						22 000
27						22 000
28						22 000
29						22 000
30						22 000
31						22 000
TOTAL***	788 000	821 000	896 000	779 000	849 000	884 000

* Quantities rounded to nearest 1000 m^3.

** Berms (297,000 m^3) assumed to be constructed in first 2 years.

*** Totals are for an even number of years of operation; therefore, do not agree exactly with the values on Table 6.

2. LOCATIONS FOR DISPOSAL OR IMPORT OF MATERIAL

MATERIAL EXPORT (CONVENTIONAL OR SHALLOW ENTOMBED CONCEPTS)

It has been estimated that as much as 5,300,000 m^3 of excavated soil from either the shallow entombed or conventional landfill operation may have to be disposed over the life of the site (see Sec. 1.0). Although it may be possible to dispose of some of this material on the OWMC site, potentially all of it may require off-site disposal. This is a large volume of earth up to 80 truckloads per day).

A preferable disposal site(s) would have some or all of the following features:

- close proximity to the OWMC site
- large capacity to receive material over an extended time period
- adequate area to stockpile the material until sufficient volume was accumulated for levelling
- a beneficial economic use for the material.

It would also be preferable if the material could be sold or at least be hauled away at no cost to OWMC.

Several locations have been identified as potential off-site disposal areas. These are:

1. quarries and pits in the Region
2. construction projects
3. general road or railway work
4. the old Welland Canal
5. sanitary landfills for cover material
6. landfilling backfilling on lands adjacent to or mainly the OWMC facility acquired specifically for the excess soil disposed.

Of these, the locations that appear to be the most preferable are quarries and pits. A quarry is an excavation from which consolidated rock has been extracted and a pit is an excavation for the removal of unconsolidated materials such as sand or gravel. Quarries and pits are either no longer in operation and abandoned or they are still in operation and licenced by the Ministry of Natural Resources under the Pits and Quarries Act.

Licenced pits and quarries must be rehabilitated upon completion as a condition of the licence. However, the Act does not require that any additional overburden material be brought to the site other than what is left after the operation. Pits and quarries that were abandoned before licencing are not required to be rehabilitated.

Mr. Dale Scott, Supervisor, Industrial Minerals Section of the Ministry of Natural Resources (MNR) was interviewed to determine if he knew of potentiala pits or quarries in the area of the OWMC site. Mr. Scott did not feel that there was a possibility that any licenced operators would be interested in receiving the material at a cost for rehabilitation purposes since it is not a requirement of the Act. However, he felt that some pit or quarry operator may be interested in receiving the material for rehabilitation if the value of the land could be raised.

Figure 1 shows the locations of most pits and quarries in the area of the OWMC site.

Mr. Scott also mentioned that a new Aggregates Act is proposed under which an Abandoned Pit Rehabilitation Fund would be established. This fund would be administered by the MNR and money may be available to level any material hauled to backfill abandoned pits or quarries.

Mr. Scott also cautioned that if it is deemed by the MNR that the excavated material is "marketed" rather than disposed as a waste product of construction, the operation may fall under the Pits and Quarries Act and require a licence. A public hearing may be required to obtain a licence.

Mr. Glenn Birch of the Niagara District office of the MNR was also contacted. He felt that there were several quarries in the area that had the volume capacity to receive the total estimated material. He also indicated that a map was available from his office that showed the locations of all the abandoned pits and quarries in the district. This map was prepared by Mr. John Fraser, also of the Niagara District office.

MATERIAL IMPORT (ABOVE-GROUND CONCEPT)

The above-ground concept may require up to 915,000 m^3 of imported material (Section 1). Two potential sources have been identified.

1. spoil piles associated with Welland Canal construction

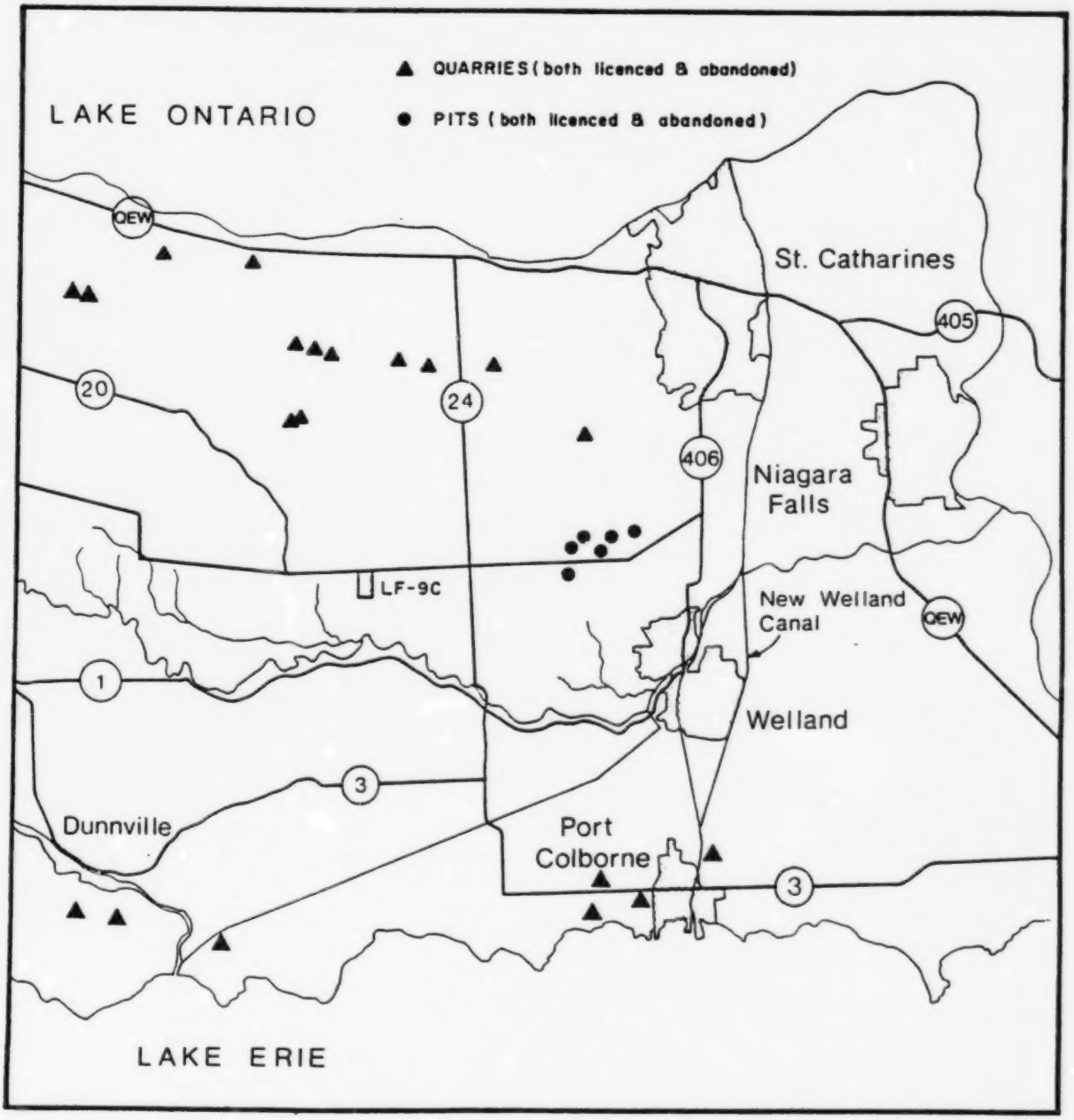


FIGURE 1

Pits and Quarries in the Vicinity of LF-9C

Gartner Lee Associates Limited

2. development of an on-site source

Spoil piles associated with the Welland Canal construction exist in the Welland area in the vicinity of the Town Line Tunnel and in particular, on the east side of canal in the near proximity of Welland. However, there is some material variability in the spoil piles, therefore testing would be required. Preliminary discussions with the Ministry of Natural Resources indicate that no licence would be needed for extracting clay from the spoil piles, but this would require confirmation on a site specific basis.

The second alternative identified would be to develop a material source adjacent to Site LF-9C. The site expansion could be incorporated into the operational plans as part of the application for the landfill hearing.

3. HYDROGEOLOGIC IMPLICATIONS OF ADDITIONAL FILL HEIGHT OVER SHALLOW ENTOMBED LANDFILL

Although the hydrogeologic impact of adding excavated material over the shallow entombed landfill was not modelled, the following results are expected.

(1) ground water "mounding" in the fill material
(2) increased downflow towards the underlying aquifer as a result of the increased hydraulic head
(3) surficial seeps (it is possible, though not proven, that this would be uncontaminated)

At this point in time, filling above ground surface level cannot be justified, other than for the purposes of promoting good surface drainage, as this would compromise the basis for selecting the shallow entombed landfill over other design concepts. However, evaluation of the impact of additional fill on top of the landfill during the Phase 4B modelling activities is possible. Therefore, a final decision on this matter should be made at that time.

Until the impact of varying amounts of additional fill over the landfill can be evaluated, complete off-site disposal should be assumed.

4. TRANSPORTATION COSTS AND FLEET SIZE REQUIREMENTS

The cost of transportation and the number of trucks required for the movement of materials associated with each landfill option is dependent upon the quality of materials and the location of disposal or source sites. The location of possible disposal and material source sites has been discerned by GLAL and recorded in Section 2.0.

The annual quantity of materials to be removed or imported varies among the three landfill concepts:

- shallow entombed
- conventional
- above-ground

Within these three concepts there are 2 waste treatment options (total solidification and partial solidification with evaporation) and three landfill development methods (cell, trench, and area). As a result each landfill concept has six separate cases which produce six different annual quantities of material. This analysis does not include all six cases, but instead it investigates only two cases for each landfill option: the maximum quantity and the minimum quantity cases, thus providing a range in cost and fleet requirments for each landfill concept.

The location of the disposal and source sites also influences cost and fleet size. GLAL identified 14 quarries and 5 pits as possible disposal sites for materials removed from the shallow entombed and conventional landfills. They also identified two alternative material source locations; an off-site location and the use of land adjacent to the site. This analysis provides information on the average haul distance for disposal of materials, and only the off-site location as a source of materials.

The 19 possible disposal locations were clustered together into six geographical locations as shown in Table 5. The average distance between site LF-9C and the central point of each of these clusters was used to estimate the maximum and minimum fleet size and cost for the disposal concepts

TABLE 5
OWMC PHASE 4B: TRANSPORTATION
COST AND FLEET SIZE FOR LANDFILL CONCEPTS

A. Potential Disposal Sites for Excess Material[1]

Location	Number of Sites	Distance from LF-9C (km)	Travel Time from LF-9C (min)
1. Pelham	6 pits	11.5	11
2. Vineland	3 quarries	12.5	12
3. Beamsville	3 quarries	17.0	16
4. Grimsby	2 quarries	25.0	23
5. Port Colborne	3 quarries	28.5	26
6. Dunnville	4 quarries	32.3	30
Average for Sites:		21.1	20

B. Potential Source Sites for Import Material[1]

Location	Description	Distance from LF-9C (km)	Travel Time from LF-9C (min)
1. Welland: Town Line Tunnel	Spoil Piles	26.75	75
2. Adjacent lands to LF-9C	Existing Soil	Adjacent	Adjacent

Notes: 1. Disposal and Source locations identified by GLAL in Section 2.

The following assumptions were used to estimate the cost of hauling material to the disposal sites, and the number of trucks required:

- maximized use of provincial highways and regional roads
- average speed of 65 km/h
- 30 minutes to load; 15 minutes to unload
- quantity of materials to be transported by truck as per Memo 3.1 by Dillon/Monenco
- 14 m^3 truck capacity
- 250 working days per year
- 8 hours working day
- transport cost rate: $1.33 per minute (as per transfer cost analysis in M.M. Dillon 1985 report: Site Selection Process - Phase 4A: Selection of a Preferred Site(s) - Transportation; Appendix G, Page G-5.).

Table 6 summarizes the transportation costs and fleet requirements for each landfill concept in association with the average haul distance for material disposal, or the material source location when importation is required. For the maximum case (shallow entombed; total solidification, area method), the movement of excess material to off-site disposal produces 109 daily truck trips. These trips would be in addition to the 89 daily truck trips generated by the movement of special wastes and additive/reagents, amounting to 198 daily one-way truck trips at site LF-9C. This 122% increase in truck traffic could produce significant impacts, and risks along the access roads (depending on the disposal site chosen), as well as at the site and site vicinity.

TABLE 6

OWMC PHASE 4B - TRANSPORTATION

COST AND FLEET SIZE FOR LANDFILL CONCEPTS

SUMMARY

TRANSPORT CONSIDERATIONS	LANDFILL CONCEPT: Shallow Entombed – Maximum Material[7]	Shallow Entombed – Minimum Material[8]	Conventional – Maximum Material[7]	Conventional – Minimum Material[8]	Above-Ground[1] – Maximum Material[7]	Above-Ground[1] – Minimum Material[8]
• Treatment Option:	Total Solid.	Part.Solid.	Total Solid.	Part.Solid.	Total Solid.	Part.Solid.
• Disposal Method:	Area Method	Trench Method	Area Method	Cell Method	Cell Method	Area Method
• Bulked Up Volume of Material[2] (m^3)	379,000	147,000	307,000	109,000	74,000	22,000
• Annual Truck Trips[3] (one-way)	27,072	10,501	21,929	7,786	5,286	1,572
• Daily Truck Trips[4] (one-way)	109	43	88	32	22	7
• Avg.Haulage[5]:						
- annual cost ($ x 10^6)	3.09	1.20	2.50	0.89	0.67	0.20
- fleet size[6]	22	9	18	6	5	2

Notes:

1. Material for above-ground will be imported.
2. 15% bulking factor as per Memo 3.1 by M.M. Dillon/Monenco.
3. Assume 14 cubic metre capacity semi dump trucks (5 axle).
4. Assume 250 working days/year.
5. Average haulage cost and fleet size based on average distance from landfill to the site material source/deposit site clusters.
6. Assume 8 hour working days; does not include spares.
7. Maximum material volume is for final year of landfill life.
8. Minimum material volume is for year 10 of landfill life.

APPENDIX D

COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

APPENDIX D

TABLE D-1

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

Criteria: Short-Term Performance
Sub-Criterion: Rate of Contaminant Transport to Aquifer

SYSTEM	RATING[1]	RATIONALE
Base Case	Low	Base case is the most basic of all of the systems and produces a low rate of contaminant transport to the underlying aquifer. This can be credited in part to the shallow entombed concept which limits the hydraulic head (i.e. ground water mound) over the landfill since it is finished level with the surrounding grade. The other key factor is the low permeability of the native clay confining layer at LF-9C that results in low rates of ground water flow out of the base of the landfill (GLAL, 1987).
1 and 2	Lowest*	System 1 and System 2 both result in the lowest rate of contaminant transport to the aquifer in the short-term. The underdrain systems can be operated such that a net inward hydraulic gradient to the landfill will be achieved. As a consequence, contaminant transport beneath the landfill will occur by the process of diffusion alone, which is slower than diffusion and advection (flow) acting together as for the other two systems. Potentially, System 2 could produce lower rates of contaminant transport than System 3 if the barrier layers in the liner system (e.g. synthetic membranes) cause slower diffusion rates than the native clays. However, this will require further detailed study to confirm; therefore System 2 and System 3 are ranked equally in this comparison (GLAL, 1987).
3	Lower	System 3 provides reductions in the contaminant transport rate to the aquifer since the perimeter drains can be utilized to lower the water table in the landfill resulting in slightly lower rates of ground water flow away from the base (GLAL, 1987).

1. Refers to best rating for sub-criterion.

TABLE D-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

Criteria: Short-Term Performance
Sub-Criterion: Rate of Contaminant Transport to Surface

SYSTEM	RATING[1]	RATIONALE
Base Case	Low	Base Case is considered to result in a low rate of contaminant transport to surface. The cover system is constructed to reflect natural conditions, and in the shallow entombed concept all of the solidified mass is buried beneath the base of the weathered zone, which is thought to be the lower limit of the local flow system. Therefore, interaction with the local flow system will be limited to the upper surface of the solidified mass and upward diffusion of contaminants in the weathered zone (GLAL, 1987).
1,2,3	Lower*	System 1, System 2 and System 3 potentially provide lower rates of contaminant transport to the surface since all three have operating leachate collection systems. These leachate collection systems will tend to maintain greater downward gradients in the cover system and therefore limit the amount of infiltration that can return to surface. Diffusion would be the main process transporting contaminants to surface under these conditions. If the barrier layer in the complex cover system of System 2 also acts as a diffusion barrier, then this system would be ranked lowest in this sub-criterion (GLAL, 1987).

1. Refers to best rating for sub-criterion.

TABLE D-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

Criteria: Short-Term Performance
Sub-Criterion: Rate of Contaminant Transport in Weathered Zone

SYSTEM	RATING[1]	RATIONALE
Base Case	Low	Although the hydrogeology of the weathered zone is not completely understood, there remains a potential that contaminants could be transported laterally to shallow off-site receptors such as bored wells and ponds. This potential is considered to be low for System 1 since the lack of any ground water mounding above the shallow entombed landfill will limit the formation of significant lateral gradients in the weathered zone. Regional lateral gradients in the weathered zone, if they exist, would be relatively low because the site is topographically very flat (GLAL, 1987).
1,2,3	Lower*	System 1, System 2 and System 3 each have actively operated leachate collection systems that would tend to produce gradients toward the landfill. Therefore these three systems are ranked as having a lower rate of contaminant transport in the weathered zone (GLAL, 1987).

1. Refers to best rating for sub-criterion.

TABLE D-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

Criteria: Long-Term Performance (non-repairable devices failure)
Sub-Criterion: All sub-criteria

SYSTEM	RATING[1]	RATIONALE
Base Case	Low	Long-term performance represents the time after the failure of any non-repairable devices. The long-term performance of the Base Case is the same as its short-term performance since it is passively operated and contains no devices that are subject to failure. This assumes that leachate of concern may still be produced in the landfill (GLAL, 1987).
1,2	Low	The liner and underdrain of System 1, and the underdrain of System 1 are non-repairable devices which can be assumed to have failed in the long-term. When this has occurred, both systems become equivalent to the Base Case. Therefore, the long-term performance rankings for System 1 and System 2 are the same as those for the Base Case, and the previous discussion of the short-term performance of the Base Case applies for these two systems in the long-term (GLAL, 1987).
3	Lower*	System 3 contains no non-repairable devices, and assuming that the perimeter drains are maintained and operated in the long-term, the ranking and discussion for the short-term performance of this system applies (GLAL, 1987).

1. Refers to best rating for sub-criterion.

TABLE D-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

Criteria: Flexibility
Sub-Criterion: Operations

SYSTEM	RATING[1]	RATIONALE
Base Case	Low	With the selection of the landfill concept (shallow entombed landfill) the flexibility in operations becomes limited to an active or passive operation. The Base Case cannot be operated actively as there is no leachate collection system. Contingency measures may identify methods for active operation at some point in the future.
1	Intermediate*	System 1 must be operated actively due to the presence of the complex liner prohibiting a controlled release of the leachate. However, degradation of the liner may permit this system to operate in a passive mode.
2,3	Intermediate*	Systems 2 and 3 are actively operated; however, they do not have a complex liner and thus may be operated in a passive mode. For passive operation the facility design must ensure that infiltration through the cover is not greater than the infiltration through the liner. If this is not the case a leachate mound will develop, possibly resulting in losses to the near surface weathered zone and surface waters. Only Systems 2 and 3 have any flexibility in their mode of operations in the short-term (tens of years). Note: All systems developed are based on the shallow entombed landfill concept. This concept does have the flexibility of being converted to a conventional landfill configuration. In this sense, the four systems developed all have flexibility in conceptual development.

1. Refers to best rating for sub-criterion.

TABLE D-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

Criteria: Reliability
Sub-Criterion: Regular Maintenance Requirements

SYSTEM	RATING[1]	RATIONALE
Base Case	Low*	The Base Case is a passive operation with no leachate collection system. Therefore, there is very little maintenance required and a high system reliability.
1,2,3	Intermediate	For the three actively operated systems, regular maintenance will be necessary for the pumping system. Maintenance is required for the collection systems, only where there are repairable devices being used (System 3 only).

1. Refers to best rating for sub-criterion.

TABLE D-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

Criteria: Reliability
Sub-Criterion: Spares - Requirement

SYSTEM	RATING[1]	RATIONALE
Base Case	Low*	Spares are not required for passive system.
1	Intermediate	A large number of spares is not required and they are readily available
2	Intermediate	See above
3	Intermediate	See above.

1. Refers to best rating for sub-criterion.

TABLE D-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

Criteria: Reliability
Sub-Criterion: Spares - Availability

SYSTEM	RATING[1]	RATIONALE
Base Case	Not Applicable	Spares are not required for passive system.
1,2,3	High	Required materials for Systems 1, 2 and 3 should be readily available.

1. Refers to best rating for sub-criterion.

TABLE D-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

Criteria: Reliability
Sub-Criterion: Proven Technology

SYSTEM	RATING[1]	RATIONALE
All Systems	Yes	All systems are proven technology with finite life expectancy.

1. Refers to be-t rating for sub-criterion.

TABLE D-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

Criteria: Reliability
Sub-Criterion: Long-Term Maintenance Requirements

SYSTEM	RATING[1]	RATIONALE
Base Case	Low*	This system does not include any devices which require continuous operation; therefore, there is no control system to operate or maintain. Maintenance on the system will be limited to periodic work on the cover (simple) system.
1	Intermediate	This system contains an actively operated leachate collection system consisting of an underdrain layer. The complex liner and collection systems are of a non-repairable nature and therefore, will be difficult to maintain after installation. The one portion of the leachate collection system which is repairable is the pumping station. Maintenance will be limited to periodic work on the cover (complex) system and routine maintenance to the leachate pumping station.
2	Intermediate	This system is very similar to System 1 with an actively operated leachate collection system (underdrain layer). In this case a native clay base/simple cover combination are used. Maintenance again will be limited to periodic work on the cover (simple) system and routine maintenance to the leachate pumping station.
3	Intermediate	This system will also require periodic maintenance on the cover (simple) system. The leachate collection system consists of a perimeter drain which is repairable, or replaceable, in nature. Therefore, the collection system (including a pumping station) will require periodic maintenance and/or replacement.

1. Refers to best rating for sub-criterion.

TABLE D-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

Criteria: Safety
Sub-Criterion: Occupational Risk During Normal or Upset Conditions and Environmental Risks on Upset Conditions

SYSTEM	RATING[1]	RATIONALE
All Systems	Low	In all cases the shallow entombed landfill concept provides for low occupational and environmental risk during either normal or upset conditions. Although marginal variances may be cited between systems, these variances should not result in any substantial increase in occupational or environmental risk. The physical facility design is such that occupational risk is minimized. The time frame for any environmental reactions is such that risk to the environment is low and can be controlled by the engineering facilities design, mitigation and/or contingency measures.

1. Refers to best rating for sub-criterion.

TABLE D-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

Criteria: Operations
Sub-Criterion: Ease of Monitoring - Performance/Environmental

SYSTEM	RATING[1]	RATIONALE
Base Case	Intermediate[2]	This subcriterion relates to the ability of the OWMC to physically monitor the functioning of the leachate control features in the landfill design and leachate migration in the surrounding environment. The intermediate rating does not relate as much to the ability of mechanical devices to monitor but the number of monitors required.
1	Intermediate	See above.
2	Intermediate	See above.
3	Intermediate	See above.

1. Refers to best rating for sub-criterion.
2. Preliminary rating only.

TABLE D-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

Criteria: Operations
Sub-Criterion: Off-Site Effects - Material Import

SYSTEM	RATING[1]	RATIONALE
Base Case	Low	No materials required.
1,2	High	Approximately 2 trucks per day required on average to import granular material. Some minimal import of synthetic membrane and pipe also required.
3	Intermediate	Pipe and some granular material imports required.

1. Refers to best rating for sub-criterion.

TABLE D-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

Criteria: Operations
Sub-Criterion: Off-Site Effects - Noise and Dust

SYSTEM	RATING[1]	RATIONALE
All	Low	Noise and dust analyses not complete (to be undertaken by impact assessment consultants with technical input from engineering).

1. Refers to best rating for sub-criterion.

TABLE D-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

Criteria: Commercial and Economic
Sub-Criterion: Active Facility Costs

SYSTEM	RATING[1]	RATIONALE
All		General The landfill costing carried out for evaluation of landfill concepts is updated to reflect the following: - typical inflow volumes for the solidified mass; - incorporation of the operations and devices for the balanced systems developed. To permit comparison of the systems which may have differing landfill lives, the costs are expressed in a unit rate per cubic metre of solidified mass. The total costs are based on the net present value including both capital and operating costs for the active operating life of the landfill. For these calculations a net discount rate of 4% was used. This rate was selected to be consistent (approximately) with the parameters for the economic analysis identified in the Monenco report entitled: "Site Selection Process Phase 4A: Selection of Preferred Site(s) - Engineering Summary.
Base Case	Lowest*	$ 9.00 unit rate per cubic metre of solidified mass
1	High	$20.78 unit rate per cubic metre of solidified mass
2	Intermediate	$10.81 unit rate per cubic metre of solidified mass
3	Low	$ 9.73 unit rate per cubic metre of solidified mass

1. Refers to best rating for sub-criterion.

TABLE D-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

Criteria: Commercial and Economic
Sub-Criterion: Post-Active Facility Costs

SYSTEM	RATING[1]	RATIONALE
Base Case	Low*	For a passive operation post-closure activities are limited to monitoring, inspection and periodic maintenance. Therefore Base Case is low.
1,2	Intermediate	Systems 1 and 2 are actively operated; however, both contain devices with finite life expectancy. Therefore, they will revert to a passive operation unless they are converted to System 3. For this reason Systems 1 and 2 are ranked intermediate on the evaluation table.
3	High	System 3 is the only actively operated system which can be maintained in the long-term, because of this it will remain an actively operated system and have the highest post-active facility cost.

1. Refers to best rating for sub-criterion.

TABLE D-1 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF SYSTEMS OF DEVICES

Criteria: Commercial and Economic
Sub-Criterion: Landfill Capacity

SYSTEM	RATING[1]	RATIONALE
Base Case	Low[2]	13 years. Greater landfill life because system does not have undergrain layer or complex liner.
1	Low	11.5 years.
2	Low	12.5 years.
3	Low	13 years. Greater landfill life because system does not have underdrain layer or complex liner. General The landfill life is directly related to land use efficiency. An underdrain layer and/or complex liner has the effect of reducing the net depth of fill which can be placed in the site, assuming the depth of clay overlying the aquifer is maintained. An underdrain layer and/or complex liner at the base of the fill zone will have a net result of reducing the landfill life with a common development method. To achieve appreciable gains in the landfill life the alternative development methods must be considered. For example, from the cell to trench method the landfill life can increase by approximately 10%, and from the trench to area method it can increase by up to 100% for the shallow entombed landfill concept.

1. Refers to best rating for sub-criterion.
2. All landfill lives are less than 20 years (minimum suggested acceptable) and therefore all are ranked as low. The calculations assume cell method of development.

APPENDIX D

TABLE D-2

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF DEVELOPMENT METHODS FOR PREFERRED SYSTEMS OF DEVICES

CRITERIA/ SUB-CRITERIA	RATING	SYSTEM	RATIONALE
Short and Long-Term Performance	Low	All	Each cell or trench acts independently but very similarly to the area method. If the cells or trenches were placed closer together, they would interact hydrogeologically, but the overall result would tend towards a similarly sized area development (GLAL, 198&). The rate of contaminant transport to the aquifer will not vary among the methods. However, the concentration of contaminants will be higher for area development because the volume of contaminants is greater for a given area.
Flexibility	Low	All	The design flexibility for operations will not be affected by implementation of alternative development methods; therefore, this will not affect the initial evaluation.
Reliability - Regular Maintenance Requirements	Low	All	The reliability of the regular maintenance requirements (including the reliability and availability of spares) will not be affected by the implementation of alternative development methods; therefore, this will not affect the initial evaluation.
Reliability - Spares	Low	All	The requirement for spares will not be affected by the implementation of alternative development methods. The availability of spares is not applicable to the evaluation
Reliability - Proven Technology	Yes	All	All of the technologies are considered to be proven.

TABLE D-2 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF DEVELOPMENT METHODS FOR PREFERRED SYSTEMS OF DEVICES

CRITERIA/ SUB-CRITERIA	RATING	SYSTEM	RATIONALE
Reliability - Long-Term Maintenance Requirements	Low	All	The long-term maintenance requirements do not change for alternative development methods; therefore, this will not affect the outcome of the initial evaluation.
Safety - Occupational risk during normal or upset conditions and environmental risk during upset conditions	Low	All	Occupational and environmental risk will not be affected by alternative development methods; therefore, this will not affect the initial evaluation.
Operations - Ease of Monitoring	Intermediate	All	With development methods from cell to trench to area the monitoring ability decreases somewhat due to less discrete fill area. This may not be a significant concern for the consideration of the alternative development methods as the hydrogeologic performance modelling has indicated that leachate movement will be vertical and very slow (in the order of thousands of years) (GLAL, 1987)

TABLE D-2 (continued)

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF DEVELOPMENT METHODS FOR PREFERRED SYSTEMS OF DEVICES

CRITERIA/ SUB-CRITERIA	RATING	SYSTEM	RATIONALE
Operations - Off-Site Effects (transport of materials)	Low	All	Under typical conditions, trench and area development requires continuous excavation and cell development requires two peak excavation periods. However, excavation timing may be altered if required because total excavated material does not change, therefore it is assumed that there is no difference between methods.
Commercial and Economic - Active Facility Costs	High Intermediate Low*	Cell Trench Area	$10.81 $/cu.m. $ 9.67 $/cu.m. $ 5.39 $/cu.m. Lowest cost because of increased landfill life. Note: Unit costs based on net present value divided by total site capacity. Future costs discounted at 4%. Costs based on "Typical Operations Case"

* Refers to best rating for sub-criterion.

TABLE D-2

RATIONALE FOR RATING FOR COMPARATIVE EVALUATION OF DEVELOPMENT METHODS FOR PREFERRED SYTEMS OF DEVICES

CRITERIA/ SUB-CRITERIA	RATING	SYSTEM	RATIONALE
Commercial and Economic Post-Active Facility Cost	Low	All	Since the same system of devices is employed for the development methods, the only difference is in relation to the area of coverage of these devices. Therefore devices maintenance may be slightly higher for area development. However, these devices will fail in long term. Therefore no applicable difference in long-term costs are anticipated.
Commercial and Economic - Landfill Capacity	Low	Cell	12.5 years landfill life.
	Low	Trench	14 years landfill life.
	High*	Area	28.5 years landfill life.

* Refers to best rating for sub-criterion.

APPENDIX E

PRELIMINARY EVALUATION - TRANSPORTATION OF SOLIDIFIED MATERIAL TO LANDFILL (DRAFT)
MONENCO LIMITED - 1986

PRELIMINARY EVALUATION

TRANSPORTATION OF SOLIDIFIED

MATERIAL TO LANDFILL

DRAFT

8 October 1986

1.0 INTRODUCTION

This document presents the techno-economic evaluation of the options available to transfer solidified material from the high solids treatment system of the solidification plant, to the landfill. The output of this evaluation is a recommendation based on the technical and economic considerations.

Due to the decision by OWMC to limit the operation of the engineered landfill to daylight hours only, interim storage for high solids solidified material produced during other operating hours is required. This study investigates the interim storage of the high solids solidified material and the transfer to the active landfill area. (Low solids solidified material is normally produced and transferred to the landfill during a single day shift, and is therefore not included in the study.)

The two options considered are:

- o belt conveyor system
- o trucks or trailers

2.0 BASIS OF EVALUATION

The following form the starting point of the evaluation:

- o evaluation of options at a Facility capacity of 150 000 t/a and the "typical operation" scenario as the basis for the quantities of solidified material to be transported to the landfill,

- o the distance to the active landfill area is taken as half the distance between the furthest and nearest areas which will be developed over the life of the Facility,

- the cost estimate of the two options is the total annual cost for the quantities of solidified material generated in year 5 of operation (assuming constant 1986 dollars),

- OWMC intend to receive solidified material at the landfill and operate it during daylight hours only. Solidified material produced in the day shift will be transported direct to the landfill area but an interim storage building near the solidification plant is provided to hold the solidified material produced in other shifts, and transported to the landfill during daylight hours,

- the solidified material will be transferred to landfill 250 days per year,

- the interim storage building has a nominal capacity equivalent to four shifts production, and

- the material in the interim storage building is protected from precipitation and run off so that no leachate is generated in this area.

The quantity of solidified material for year 5 of the operation is as follows:

o solidified material		84 600 t
o incinerator slag		2 700
	Total	87 300 t

The landfill will be operated in daylight hours and the annual quantity must be handled in 250 days (50 wks/a, 5 days/wk). The quantity of material that must be transferred each day is about 350 t. Based on an 8 hour shift, the average hourly transfer rate is about 44 t/h. (Equipment is sized to accommodate surge rates that are double the average transfer rate.)

The normal interim storage requirement is two shifts production. To provide flexibility, the interim storage building is sized to store 4 shift production of solidified material. The required capacity of the interim storage building is about 600 t ($350\ t \times \frac{4\ shifts}{2.4\ shifts}$).

Note: The average production of solidified material is accomplished in 12 shifts (of 8 hours each) per week, which is equivalent to 2.4 shifts per day.

The interim storage building is divided into two sections, each with a capacity of 300 t.

3.0 DESCRIPTION OF MATERIAL HANDLING SYSTEM

The two options for transferring high solids solidified material and incinerator slag to the landfill are:

- o belt conveyor system
- o trucks or trailers.

The two options incorporate identical equipment to the interim storage building. From the solidification plant, the high solids material is transferred by belt conveyor to the interim storage building. The interim storage building is located in the landfill site area on the outside of the central operating area fence.

During the day shift, the high solids material bypasses the interim storage building and is transported directly to the landfill.

A detailed description of each of the two options is contained in the following sections.

3.1 Belt Conveyor System

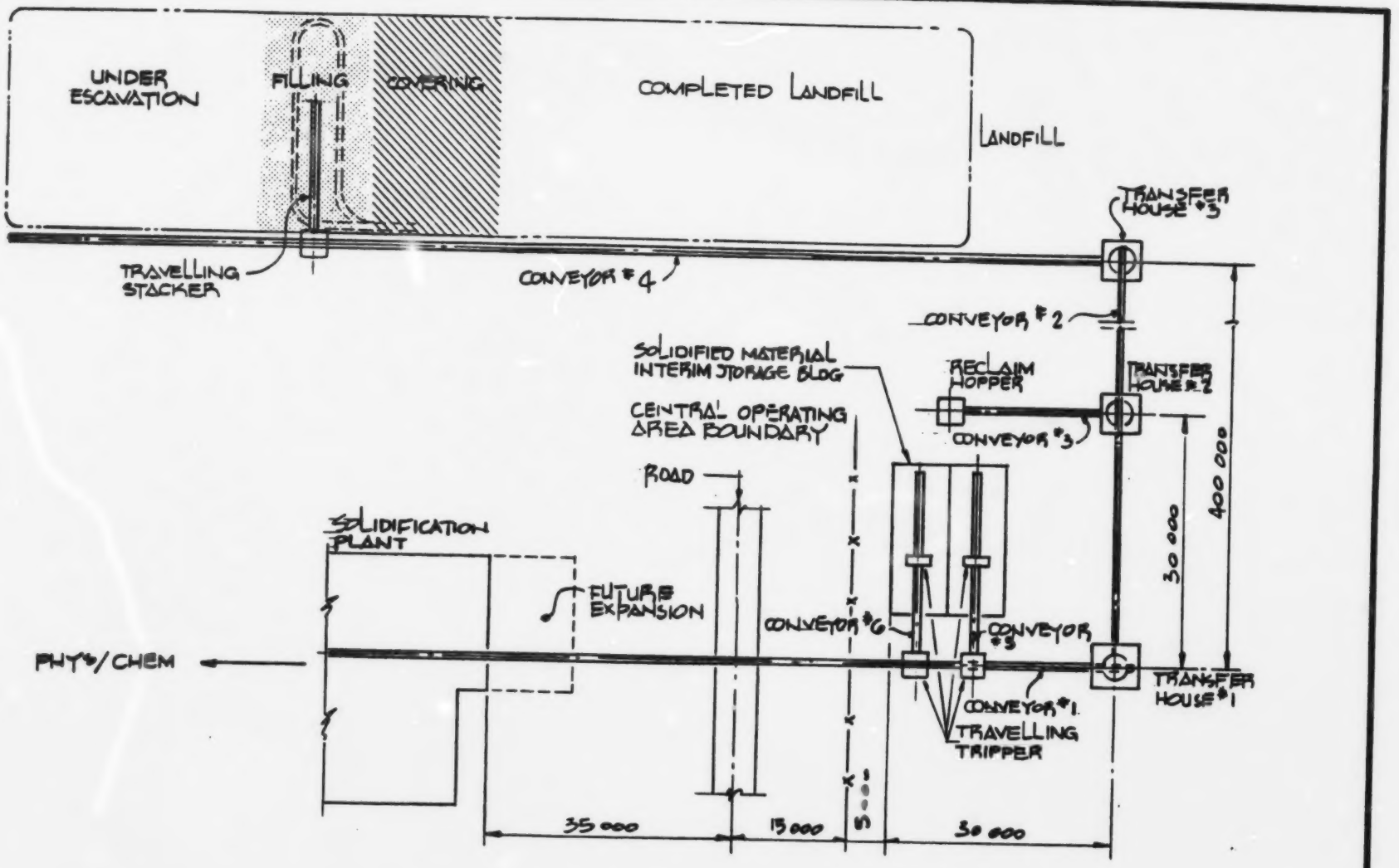
The overall layout of the conveying system is shown on Figure 1 and described as follows. Conveyor 1, which carries the solidified material from the mixers. crosses the process plant boundary and ends at transfer house 1. When the landfill is not receiving material, the travelling tripper on conveyor 1 discharges the material onto either conveyor 5 or conveyor 6. Each of these conveyors is also fitted with a travelling tripper which discharges the solidified material into the interim storage area.

During the day shift, the solidified material bypasses the travelling tripper on conveyor 1 and is transferred to conveyor 2 at transfer house 1. Conveyor 2 carries the material to transfer house 3 where it is transferred to conveyor 4, from which a travelling stacker discharges the material into the landfill.

During the day shift, it is also required to reclaim solidified material from the interim storage building. A front-end loader reclaims the material and dumps it into the reclaim hopper from which it is fed onto conveyor 3 and carried to transfer house 2. At transfer house 2, the material is transferred onto conveyor 2 and carried to the landfill cell as previously described.

It should be noted that in deriving the described system, a rigorous optimization and equipment selection was not performed. The preferred system was selected based on engineering experience and information provided by equipment suppliers. The main criteria considered in system selection included:

- efficient stacking and reclaiming of material in temporary storage building,
- efficient stacking of material in active landfill,
- reliability of all equipment, and
- capital and operating cost estimates.



NOTE :
ALL DIMENSIONS IN mm

FIGURE 1
LANDFILL TRANSPORTATION EVALUATION
TYPICAL LAYOUT - CONVEYOR SYSTEM

3.2 Trucking System

The overall layout of the system for trucking the solidified material is shown on Figure 2 and described as follows. Conveyor 1, which carries the solidified material from the mixers, crosses the process plant boundary and ends at the truck load-out station. When the landfill is not receiving material, the travelling tripper on conveyor 1 discharges the material onto either conveyor 2 or conveyor 3. Each of these conveyors is also fitted with a travelling tripper which discharges the solidified material into the interim storage building.

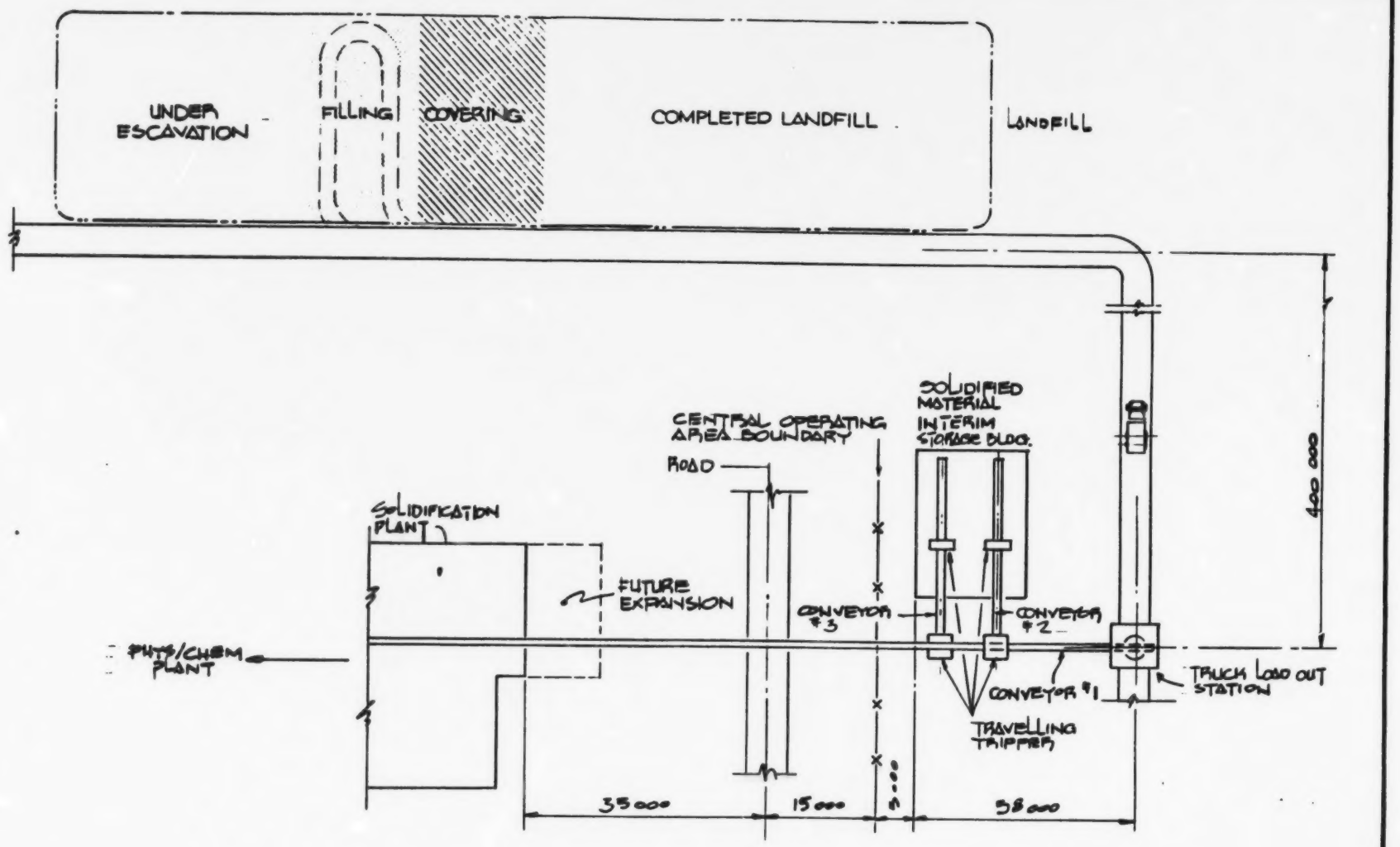
During the day shift, the solidified material bypasses the travelling tripper on conveyor 1 and is carried onto the truck load-out station. The truck load-out station consists of a storage silo fitted with a live-bottom to aid removal and loading into trucks. To provide flexibility in the system, the storage capacity of the truck loading station is 3 hours of the solidification plant capacity.

The material which is stored in the interim storage building is reclaimed by front-end loader and loaded into trucks and transferred to the landfill.

Dump trucks transport the solidified material to the working area of the landfill. Assuming an average truck load of 25 t, 14 loads are required to dispose of 350 t/d. The cycle time for each truck load is 40 minutes, resulting in 9.3 hours of trucking time per day. This can be accomplished by 2 trucks, each operating for under 5 h/d, as a conservative estimate.

3.3 Slag and Solidified Material from Incineration Plant

The solidified material and slag that is generated at the incineration plant will have transportation facilities to remove the material. The incinerator slag will be transported in dumpsters, and the solidified material will be transported in dumpsters and/or trucks. Since these methods can deliver the material to either the interim storage building or to the appropriate point in the transportation system (truck load-out



NOTE :
ALL DIMENSIONS IN mm

FIGURE 2
LANDFILL TRANSPORTATION EVALUATION
TYPICAL LAYOUT - TRUCK SYSTEM

station or one of the transfer houses), the activities will be the same for each of the alternatives. Therefore transport of slag and solidified material from the incineration plant are not included in the evaluation.

It should be noted that even though the landfill operates only 5 days per week, the incineration plant operates 7 days per week. Therefore, some of the slag and solidified material from the incineration plant will be delivered to the interim storage building during the weekend.

4.0 COST ESTIMATE

The cost estimate provides the total annual costs for each of the options. As previously noted, costs are calculated based on a landfill active area distance halfway between longest and shortest distances from the solidification plant. This is an "order of magnitude" cost estimate, developed for the comparison of the alternative transportation systems.

4.1 Capital Cost and Annual Cost of Capital

The capital costs for each of the options are summarized on Tables 1 and 2. The central operating area boundary is the starting point for estimation of capital cost.

In order to derive the annual cost for each option, the cost of capital is required. Based on an 11% interest rate amortized over 20 years (same criteria as for site selection), the capital recovery factor is 0.1256.

Therefore, the annual cost of capital for each option is as follows:

- o conveyor option ($4,000,000 x 0.1256) $502,000
- o trucking option ($1,200,000 x 0.1256) $151,000

TABLE 1

LANDFILL TRANSPORTATION STUDY - CONVEYOR OPTION

SUMMARY OF CAPITAL COST

Mechanical Equipment	$2,211,400
Transfer Houses & Reclaim Hopper	112,500
Galleries & Bents	450,400
Foundations	130,500
Stacker Rails	197,000
Temporary Storage Building	270,000
Electrics & Controls	221,500
Access Road	26,000
	$3,619,300
Contingency (10%)	362,000
	$3,981,300

Total $4,000,000

TABLE 2

LANDFILL TRANSPORTATION STUDY - TRUCKING OPTION

SUMMARY OF CAPITAL COST

Mechanical Equipment	$ 428,400
Load Out Station	120,500
Galleries & Bents	88,700
Foundations	60,500
Temporary Storage Building	270,000
Electrics & Controls	43,000
Roads for Transfer of Product to Landfill	52,000
	$1,063,100
Contingency (10%)	107,000
	$1,170,100

Total $1,200,000

4.2 Annual Operating Cost

As previously noted, the landfill will operate during the day shift only, 5 days per week.

The annual operating cost for each of the options is summarized in Tables 3 and 4.

Cost of power and maintenance is calculated at 3% of capital cost. The cost of the front-end loader is at a rate of $55/h including machine, operator, maintenance and all consumables. An hourly truck rate of $80 is applied, which is the rate used in all cost estimates for this project. The annual cost of an operator is $36,000.

5.0 EVALUATION OF ALTERNATIVES

5.1 Criteria for Evaluation

The set of criteria used to evaluate the two alternatives are the same as those used in Chapter 3 of the report for other evaluations. The criteria used are as follows:

- Performance
- Flexibility
- Reliability
- Safety
- Operations
- Commerce and Economics
- Canadian/Ontario Benefits.

TABLE 3

LANDFILL TRANSPORTATION STUDY - CONVEYOR OPTION

SUMMARY OF ANNUAL COST

1.	Cost of Capital	$502,000
2.	1 man for operating conveyor system	36,000
3.	Maintenance	66,000
4.	Electrical Power	66,000
5.	Front End Loader	110,000
6.	Road Maintenance	3,000
	TOTAL ANNUAL COST	$783,000

TABLE 4

LANDFILL TRANSPORTATION STUDY - TRUCKING OPTION

SUMMARY OF ANNUAL COST

1.	Cost of Capital	$151,000
2.	1 man for operating conveyor and load out station	36,000
3.	Maintenance	13,000
4.	Electrical Power	13,000
5.	Front End Loader	110,000
6.	Trucking Cost	280,000
7.	Road Maintenance	5,000
	TOTAL ANNUAL COST	$608,000

A set of sub-criteria have been developed below and, again, are very similar to the criteria developed in Chapter 3 for other evaluations. These sub-criteria are intended to show how well each of the alternatives meet OWMC's goals to:

- o minimize risk to human health
- o minimize environmental impacts; and
- o minimize financial costs to the people of Ontario.

The ratings for the sub-criteria have been scaled as either high, intermediate or low. When quantitative values are used to measure the criterion, the ratings are scaled relative to the real values for each alternative. Subjective judgments have been applied to develop ratings for sub-criteria that have not be quantified.

The sub-criteria are also intended to reflect the ability of each alternative to meet the transportation requirements. The criteria and sub-criteria are defined below.

Performance

This criterion relates to OWMC's goals of minimizing adverse risks to human health and impacts on the environment.

The performance characteristics of the alternative solidified material transportation systems were compared on the basis of the following sub-criteria:

- o The relative ability and efficiency of each to meet the transporation requirements.

- o Is the alternative a "proven technology", in terms of the extent to which it is used in similar industrial applications.

Flexibility

This criterion relates to the ability of the alternative systems to handle changes in the solidified material quantities. It relates to all of OWMC's corporate goals.

The comparative flexibility of alternatives was evaluated with consideration of the following sub-criteria:

- o Sensitivity to variation in feed rate of solidified material to the landfill.
- o Ease of start-up and shut-down.
- o Sensitivity to changes in climatic conditions (winter operation for example).
- o Design flexibility - the number of alternatives available for consideration.
- o Turn down - the ability to operate at partial loads.

Reliability

The "reliability" criterion measures the ability of a technology to meet the transportation requirements. Therefore, this criterion focuses on the physical components of the systems, the extent of their maintenance requirements, the need for spare parts, the general robustness of the design and its vulnerability to breakdown.

A reliable system is necessary to meet all three of OWMC's corporate goals.

The reliability of the alternatives to perform in a consistent manner was compared using the following sub-criteria:

- o Maintenance requirements during normal operation.
- o Vulnerability to interruption of operation.
- o Recovery from interruption
- o Equipment spares:
  - spare parts required
  - availability of spare parts.
- o Robustness of the equipment.

Operations

The "operations" criterion ensures that the selected system is not only capable of transporting the solidified material, but does so in a practical manner. The complexity of the systems and the difficulty of start-up and

shut-down are therefore assessed. In addition, the effect of each system on landfill operations and the environment are assessesd.

Several operational factors were considered in comparing alternative systems, such as:

- o The complexity of the system and its associated equipment.
- o The degree of automation.
- o Effect of landfill operations.
- o Nuisance in terms of:
  - visual
  - noise
  - dust.

Safety

Results of evaluation of the "safety" criterion are the most direct means by which OWMC measures the degree to which the systems achieve its first two goals: to minimize impacts on human health and the environment.

The safety aspects of the alternatives were assessed and compared on the basis of:

- o The environmental risks which may occur during normal and upset conditions;
- o The occupational risk posed by the alternative during normal operation and upset conditions.

Commercial and Economic

The commercial and economic factors considered are as follows:

- o Capital cost;
- o Annual operating cost.

Canadian/Ontario Benefits

- No sub-criteria.

5.2 Comparative Evaluation

The comparative evaluation of the alternative transportation system was performed based on the criteria established in the preceding section and is presented in Table 5.

5.3 Main Findings

The comparative evaluation of the alternatives presented in Table 5 results in a high rating for the trucking system due to the reasons stated below.

- The preferred method of landfill development (area method) requires the delivery of solidified material to the active working area that is continually advancing. The trucking system will accomplish this need more efficiently and with more flexibility than the conveyor system which needs periodic relocation.

- The trucking system is less vulnerable to interruptions in operation. Transportation of solidified material by one truck is possible even if the other truck is out of service. Trucking of reclaimed material from the interim storage building is also possible during a power failure. The conveyor system, on the other hand, is made up of several elements and the failure of any one of the elements will render the system inoperable.

- The trucking system can also recover from interruptions more readily, as it may be possible to get a replacement truck in a short time while major repairs to the conveyor system can take longer. This, combined with the preceding point, provide for higher reliability of the trucking system.

- The trucking system is less complex and simple to operate and has less potential for interference with landfill operations than the conveyor system.

TABLE 5

COMPARATIVE EVALUATION OF SOLIDIFIED MATERIAL TRANSPORT SYSTEM

CRITERIA	SUB-CRITERIA	TRUCKED	CONVEYOR	REMARKS
PERFORMANCE	o ABILITY AND EFFICIENCY TO MEET TRANSPORTATION REQUIREMENTS	HIGH*	INTERMEDIATE	AS ACTIVE LANDFILL AREA ADVANCES, FEED CONVEYOR MUST BE MOVED, CONTRIBUTING TO LOWER EFFICIENCY.
	o PROVEN TECHNOLOGY - EXTENT USED IN SIMILAR APPLICATIONS	HIGH	HIGH	BOTH SYSTEMS ARE WIDELY USED ELSEWHERE.
FLEXIBILITY	o SENSITIVITY TO VARIATION IN FEED RATE	LOW	LOW	BOTH SYSTEMS ARE FLEXIBLE. ALSO, QUANTITY FROM HIGH SOLIDS SYSTEM DOES NOT VARY FOR HIGH SOLIDIFICATION SCENARIO.
	o EASE OF START-UP AND SHUT-DOWN	HIGH	HIGH	SMALL TRUCK FLEET IS EASY TO MOBILIZE. CONVEYOR SYSTEM ONCE IN PLACE AT ACTIVE AREA, IS EASY TO START-UP AND SHUT-DOWN.
	o SENSITIVITY TO CHANGES IN CLIMATIC CONDITIONS	INTERMEDIATE	INTERMEDIATE	BOTH SYSTEMS CAN OPERATE UNDER CLIMATIC CONDITIONS THAT ALLOW LANDFILL OPERATIONS.
	o DESIGN FLEXIBILITY	HIGH*	INTERMEDIATE	CONVEYOR SYSTEM NEEDS PERIODIC RELOCATION AS ACTIVE LANDFILL AREA ADVANCES.
	o TURN-DOWN	HIGH	HIGH	BOTH SYSTEMS ARE CAPABLE OF TURN-DOWN OPERATION.

* INDICATES BEST RATING FOR SUB-CRITERIA

TABLE 5

COMPARATIVE EVALUATION OF SOLIDIFIED MATERIAL TRANSPORT SYSTEM

CRITERIA	SUB-CRITERIA	TRUCKED	CONVEYOR	REMARKS
RELIABILITY	o MAINTENANCE REQUIREMENTS	LOW	LOW	BOTH SYSTEMS REQUIRE NORMAL MAINTENANCE INPUTS.
	o VULNERABILITY TO INTERRUPTION OF OPERATION	LOW*	HIGH	CONVEYOR SYSTEM MORE VULNERABLE AS IT IS MADE UP OF SEVERAL CONVEYORS, ANY ONE OF WHICH CAN BREAK DOWN. DURING POWER FAILURE, TRUCKING OF RECLAIM MATERIAL FROM INTERIM STORAGE IS POSSIBLE, WHEREAS CONVEYOR SYSTEM WILL BE INOPERABLE.
	o RECOVERY FROM INTERRUPTION	HIGH*	INTERMEDIATE	TRANSPORTATION POSSIBLE WITH ONE TRUCK, WHEN OTHER TRUCK IS OUT OF SERVICE. IT MAY BE POSSIBLE TO GET A REPLACEMENT TRUCK INTO SERVICE IN A SHORT TIME, WHILE MAJOR REPAIRS ON CONVEYORS CAN TAKE LONGER.
	o SPARE PARTS - REQUIREMENT - AVAILABILITY	HIGH	HIGH	REQUIREMENTS ARE AVERAGE AND AVAILABILITY IS HIGH FOR BOTH SYSTEMS.
	o ROBUSTNESS OF EQUIPMENT	HIGH	HIGH	BOTH SYSTEMS HAVE ROBUST EQUIPMENT AVAILABLE.

* INDICATES BEST RATING FOR SUB-CRITERIA

TABLE 3

COMPARATIVE EVALUATION OF SOLIDIFIED MATERIAL TRANSPORT SYSTEM

CRITERIA	SUB-CRITERIA	TRUCKED	CONVEYOR	REMARKS
OPERATIONS	o COMPLEXITY OF SYSTEM AND ASSOCIATED EQUIPMENT	LOW*	INTERMEDIATE	TRUCKING OPERATION IS VERY SIMPLE, WHILE CONVEYOR SYSTEM IS MORE COMPLEX.
	o DEGREE OF AUTOMATION	LOW	INTERMEDIATE*	CONVEYOR SYSTEM WILL HAVE INTERLOCKS. ONCE STARTED AT THE BEGINNING OF A DAY, IT IS ESSENTIALLY AUTOMATIC.
	o EFFECT OF LANDFILL OPERATIONS	LOW*	INTERMEDIATE	AS ACTIVE LANDFILL AREA CHANGES, CONVEYOR SYSTEM MUST BE MOVED PERIODICALLY. INTERFERENCES AT TRACK-OUT AREA, BERMS, ETC. ARE MORE LIKELY.
	o NUISANCE IN TERMS OF: - VISUAL - NOISE - DUST	INTERMEDIATE	LOW*	CONVEYOR SYSTEM COMPRISES INSTALLED STRUCTURES AND IS VISIBLE. HOWEVER, TRUCKS WILL GENERATE MORE NOISE, ESPECIALLY WHEN REVERSING. TRUCKING SYSTEM WILL GENERATE MORE DUST AND FUMES.
SAFETY	o ENVIRONMENTAL RISK DURING NORMAL AND UPSET CONDITIONS	LOW	LOW	IN BOTH ALTERNATIVES, THERE IS LITTLE LIKELIHOOD OF A CONTAMINANT PATHWAY TO THE ENVIRONMENT.
	o OCCUPATIONAL RISK DURING NORMAL OR UPSET CONDITIONS	INTERMEDIATE	LOW*	TRUCK TRAFFIC HAS HIGHER POTENTIAL FOR ACCIDENTS.

* INDICATES BEST RATING FOR SUB-CRITERIA

TABLE 5

COMPARATIVE EVALUATION OF SOLIDIFIED MATERIAL TRANSPORT SYSTEM

CRITERIA	SUB-CRITERIA	TRUCKED	CONVEYOR	REMARKS
COMMERCIAL AND ECONOMIC	o CAPITAL COST	LOW*	HIGH	BASED ON AN 'ORDER OF MAGNITUDE' ESTIMATE, CONVEYOR SYSTEM IS APPROXIMATELY 3 TIMES MORE EXPENSIVE.
	o ANNUAL OPERATING COST	INTERMEDIATE*	HIGH	CONVEYOR SYSTEM IS APPROXIMATELY 30% MORE EXPENSIVE.
CANADIAN/ ONTARIO BENEFITS	NO SUB-CRITERIA			REQUIREMENTS OF BOTH SYSTEMS CAN BE CATERED TO BY SOURCES IN ONTARIO.

* INDICATES BEST RATING FOR SUB-CRITERIA

- o The economics, both capital cost and annual operating cost, of the trucking system are far more attractive than the conveyor system.

The trucking system has the following minor disadvantages:

- trucks are likely to generate more noise, especially during reversing, as well as more dust and fumes than the conveyor system, thus contributing to nuisance, and

- truck traffic has a higher potential for accidents.

However, in perspective, these are minor disadvantages when considering the overall landfill operations comprising much greater truck traffic for the movement of excavated earth from the landfill area and the level of activity contributed by heavy earth moving equipment.

6.0 RECOMMENDATION

It is recommended that the trucking system be selected for the preliminary design of the Facility based on this techno-economic evaluation. The recommendation should be reviewed during the detailed design stage to ensure that it is consistent with the design information at that time.

APPENDIX F

EVALUATION OF LEACHATE TRANSMISSION SYSTEMS

TABLE F-1 - RATIONALE FOR EVALUATION OF LEACHATE TRANSMISSION SYSTEMS

RATIONALE FOR RATING COMPARATIVE EVALUATION OF LEACHATE TRANSMISSION SYSTEMS

SYSTEM	RATING	RATIONALE
Criteria:	Performance	
Sub-Criteria:	Ability to Meet Transmission Requirements	
Trucked	High	Will meet transmission requirements
Pipeline	High	Will meet transmission requirements
Criteria:	Performance	
Sub-Criteria:	Proven Technology	
Trucked	High	Trucking and pumping of leachate is currently practiced at several facilities
Pipeline	High	
Criteria:	Performance	
Sub-Criteria:	Long Term Maintenance	
Trucked	Intermediate	Consists of road and vehicle maintenance
Pipeline	Low*	Servicing of pumps and control valve system.

RATIONALE FOR RATING COMPARATIVE EVALUATION OF LEACHATE TRANSMISSION SYSTEMS (CONTINUED)

SYSTEM	RATING	RATIONALE
Criteria:	Flexibility	
Sub-Criteria:	Sensitivity to Variation in Feed Rate	
Trucked	Intermediate	If the feed rate is significantly increased, under storm or spring thaw conditions for example, the fleet size will need to be increased. The time required for organization of additional vehicles may impact landfill or plant operations. Also, additional traffic may impact landfill operations.
Pipeline	Low*	The pipeline can be designed to function at normal and peak flows. Therefore, the system will be able to handle increased flow rates up to the maximum design flow (peak flow).
Criteria:	Flexibility	
Sub-Criteria:	Sensitivity to Variation in Feed Composition	
Trucked	Low	Trucks may require a flushing system for settled suspended solids. Although leachate quality is not known at this time, corrosion resistant tanks will likely be necessary. A trucking system is capable of handling feed composition variations, provided the above considerations are taken into account.
Pipeline	Low	Gravity-flow sections of the pipeline network must provide sufficient velocity to avoid any settlement of suspended solids. Pipeline material should be corrosion resistant. Capable of handling feed composition variations, provided above considerations are taken into account.

RATIONALE FOR RATING COMPARATIVE EVALUATION OF LEACHATE TRANSMISSION SYSTEMS (CONTINUED)

SYSTEM	RATING	RATIONALE
Criteria:	Flexibility	
Sub-Criteria:	Ease of Start-up/Shut-down	
Trucked	Intermediate	Start-up of a trucking system is dependent on the availability of trucks and personnel. On holidays and weekends for example, quick start-ups may be difficult. Shut-down of a trucking system is relatively easy, but may be expensive depending on the contract agreement. If the trucks are mobilized, cost for the trip may be incurred depending on contract agreement.
Pipeline	High*	A pipeline system can have the capability for immediate start-up and shut-down as required.
Criteria:	Flexibility	
Sub-Criteria:	Sensitivity to Changes in Climatic Conditions	
Trucked	High	A trucking system may be unable to operate during certain climatic conditions. (For example, very wet conditions or blizzard conditions).
Pipeline	Low*	A pipeline should be relatively insensitive to changes in climatic conditions provided that proper protection against freeze-up.

RATIONALE FOR RATING COMPARATIVE EVALUATION OF LEACHATE TRANSMISSION SYSTEMS (CONTINUED)

SYSTEM	RATING	RATIONALE
Criteria: Flexibility Sub-Criteria: Design Flexibility		
Trucked	High*	Alterations in design quantities for transport may be handled through the change in the number of trucks, or change in the trip frequency. This system is very flexible in terms of source and disposal locations.
Pipeline	Intermediate	Changes in source location may be handled by design of the line network. This system is less flexible in terms of disposal location once in place.
Criteria: Flexibility Sub-Criteria: Turn-down - The Ability to Operate at Partial Loads		
Trucked	Intermediate	Operation at partial loads can be facilitated, but may be expensive depending on the trucking contract.
Pipeline	High*	Pipeline system design can include operation at partial loads.

RATIONALE FOR RATING COMPARATIVE EVALUATION OF LEACHATE TRANSMISSION SYSTEMS
(CONTINUED)

SYSTEM	RATING	RATIONALE
Criteria: Reliability Sub-Criteria: Regular Maintenance Requirements		
Trucked	Intermediate	Trucking will require vehicle maintenance. Constant road maintenance is necessary for effective operation of a trucking system. This may be required in any event.
Pipeline	Intermediate	Monitoring of inflow and outflow volumes in the pipeline should be made to ensure that there are no leaks. Regular pump maintenance will also be required.
Criteria: Reliability Sub-Criteria: Vulnerability to Interruption of Landfill and/or COA Operation		
Trucked	Low	A trucking system will be relatively unaffected by interruption of operation of the treatment facility or the landfill.
Pipeline	Low	A pipeline system will be unaffected by interruption of operation of the treatment facility or the landfill.

RATIONALE FOR RATING COMPARATIVE EVALUATION OF LEACHATE TRANSMISSION SYSTEMS (CONTINUED)

SYSTEM	RATING	RATIONALE
Criteria:	Reliability	
Sub-Criteria:	Equipment Spares: i) spare parts, ii) availability of spare parts.	
Trucked	Intermediate Intermediate	i) Trucking vehicles may require spare parts ii) Spare parts or temporary replacement vehicle should be provided in the trucking contract.
Pipeline	High* High*	i) Spare parts will likely consist of pumps and controls. Design should provide for 100% back-up during failure. ii) Regular pump maintenance should minimize the need for spare parts
Criteria:	Reliability	
Sub-Criteria:	Robustness of Equipment	
Trucked	Intermediate*	Trucks should be robust in nature.
Pipeline	Intermediate	Once the pipeline is underground it should require little or no maintenance or repair over the 20 years design life. The robustness of the pumps will be largely dependent upon the nature of the leachate and suitability of pumping equipment.

RATIONALE FOR RATING COMPARATIVE EVALUATION OF LEACHATE TRANSMISSION SYSTEMS (CONTINUED)

SYSTEM	RATING	RATIONALE
Criteria:	Operations	
Sub-Criteria:	Complexity of the Process and its Associated Equpiment	
Trucked	Low*	Trucking process is relatively simple; - filling of tank trucks - transport of material - emptying of trucks
Pipeline	Intermediate	A pipeline system involves a more complex system requiring a pipeline network and pumping facilities and controls.
Criteria:	Operations	
Sub-Criteria:	Degree of Automation	
Trucked	Low	Relatively low level of automation
Pipeline	High*	Automated system with level controls.

RATIONALE FOR RATING COMPARATIVE EVALUATION OF LEACHATE TRANSMISSION SYSTEMS (CONTINUED)

SYSTEM	RATING	RATIONALE
Criteria:	Operations	
Sub-Criteria:	Effect on Landfill Operations	
Trucked	Intermediate	A trucking system will result in a substantial increase in vehicular traffic on landfill access roads. This could become a problem during periods of large runoff and leachate volumes.
Pipeline	Low*	Once the pipeline is installed the system should have little effect on landfilling operations.
Criteria:	Operations	
Sub-Criteria:	Off-Site Effects: i) Visual aspects, ii) Noise, iii) Dust, iv) Odour	
Trucked	Intermediate	Trucks will result in an increase in road dust, noise and exhaust fumes; however, the extent of the impact will reflect the size of the fleet required.
Pipeline	Low*	A pipeline system will have little or no impact on the above.

RATIONALE FOR RATING COMPARATIVE EVALUATION OF LEACHATE TRANSMISSION SYSTEMS (CONTINUED)

SYSTEM	RATING	RATIONALE
Criteria: Commercial and Economic Sub-Criteria: Capital Costs		
Criteria: Commercial and Economic Sub-Criteria: Operating Costs		
Criteria: Canadian Benefits Sub-Criteria: No Sub-Criteria Developed at this Time		

TABLE 2

RATIONALE FOR RATING COMPARATIVE EVALUATION OF LEACHATE TRANSMISSION SYSTEMS (CONTINUED)

SYSTEM	RATING	RATIONALE
Criteria: Safety Sub-Criteria: Environmental Risk Posed During Normal Operations or Upset Conditions (Based on the Assumption that Leachate Quality is of Concern (Landfill PAR Draft, June 1986)		
Trucked	Intermediate	A spill during trucking has the potential to contaminate surface water; however, a truck spill will likely be localized and can normally be cleaned-up if immediate action is taken.
Pipeline	Low*	A pipeline leak will likely result in minimal impact on the environment due to the following: i) with an active leachate collection system any leakage will be collected by the underdrain system and not released. ii) flow quantities in the lines should be monitored regularly to identify leaks.
Criteria: Safety Sub-Criteria: Occupational Risk Posed During Normal Operations of Upset Conditions (Based on the Assumption that Leachate Quality is of Concern (Landfill PAR Draft, August 1986)		
Trucked	Intermediate	Bringing the leachate to surface for trucking increases the risk of human exposure.
Pipeline	Low*	There is little opportunity for human exposure to leachate other than through pump maintenance or activity in manholes.